TROCCINOX - Tropical Convection, Cirrus, and Nitrogen Oxides Experiment, Overview

Ulrich Schumann
Deutsches Zentrum für Luft- und Raumfahrt
(German Aerospace Center, DLR),
Institute of Atmospheric Physics
on behalf of the TROCCINOX team

DLR

FZ Jülich

Univ. Mainz

Univ. Frankfurt

Univ. of Lancaster

Univ. of Leeds

TROCCINOX

Tropical Convection, Cirrus and Nitrogen Oxides Experiment

UPS/LA

CNRS

IFA-CNR

SRL

INOA

IPMet/UNESP

ETH Zürich

Obs. de Neuchâtel

CAO

Stratosphere-M

...

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Acknowledgements

TROCCINOX is partially funded by the Commission of the European Community.

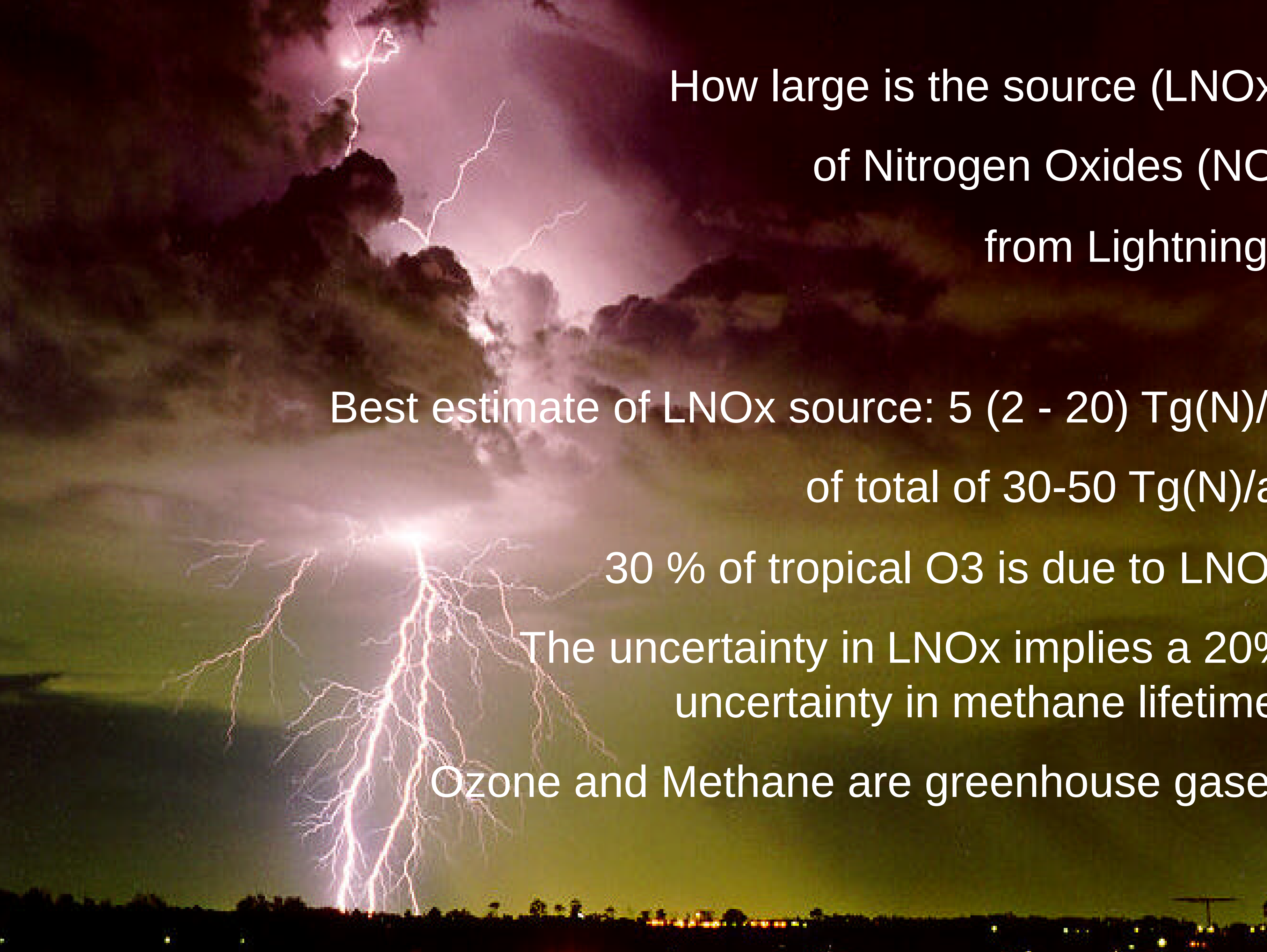
TROCCINOX is performed together with several European research institutes (ETH, KNMI, MPI-C etc.) and together with the Brazilian project TroCCiBras co-ordinated by IPMET

Support by the Instititituto de Pesquisas Meterologicas (IPMET) / Universidade Estadual Paulista (UNESP), and the company EMBRAER is gratefully acknowledged.

TROCCINOX - *Questions*

- What is the impact of tropical deep convection on the balance and distribution of NO_x and other trace gases?
- How do troposphere-stratosphere exchange processes contribute to the amount of *water vapour* entering the stratosphere?
- What is the effect of tropical deep convection on the formation and distribution of *aerosol particles*?
- What are the origins of *cirrus clouds* in the tropics and how do cirrus clouds affect air composition?
- What is the role of the main transport processes in the tropical UT/LS in determining trace gas budgets?

The Jan-March 2004 IOP provided data to answer part of the questions, in particular the NOx aspect


How large is the source (LNOx
of Nitrogen Oxides (NO
from Lightning
Best estimate of LNOx source: 5 (2 - 20) Tg(N)/
of total of 30-50 Tg(N)/a
30 % of tropical O3 is due to LNO
The uncertainty in LNOx implies a 20%
uncertainty in methane lifetime
Ozone and Methane are greenhouse gase

TROCCINOX – *Schedule: July 2002 - June 2005*

2002/2003

Preparation, Agreement of Cooperation between DLR and UNESP/IPMET

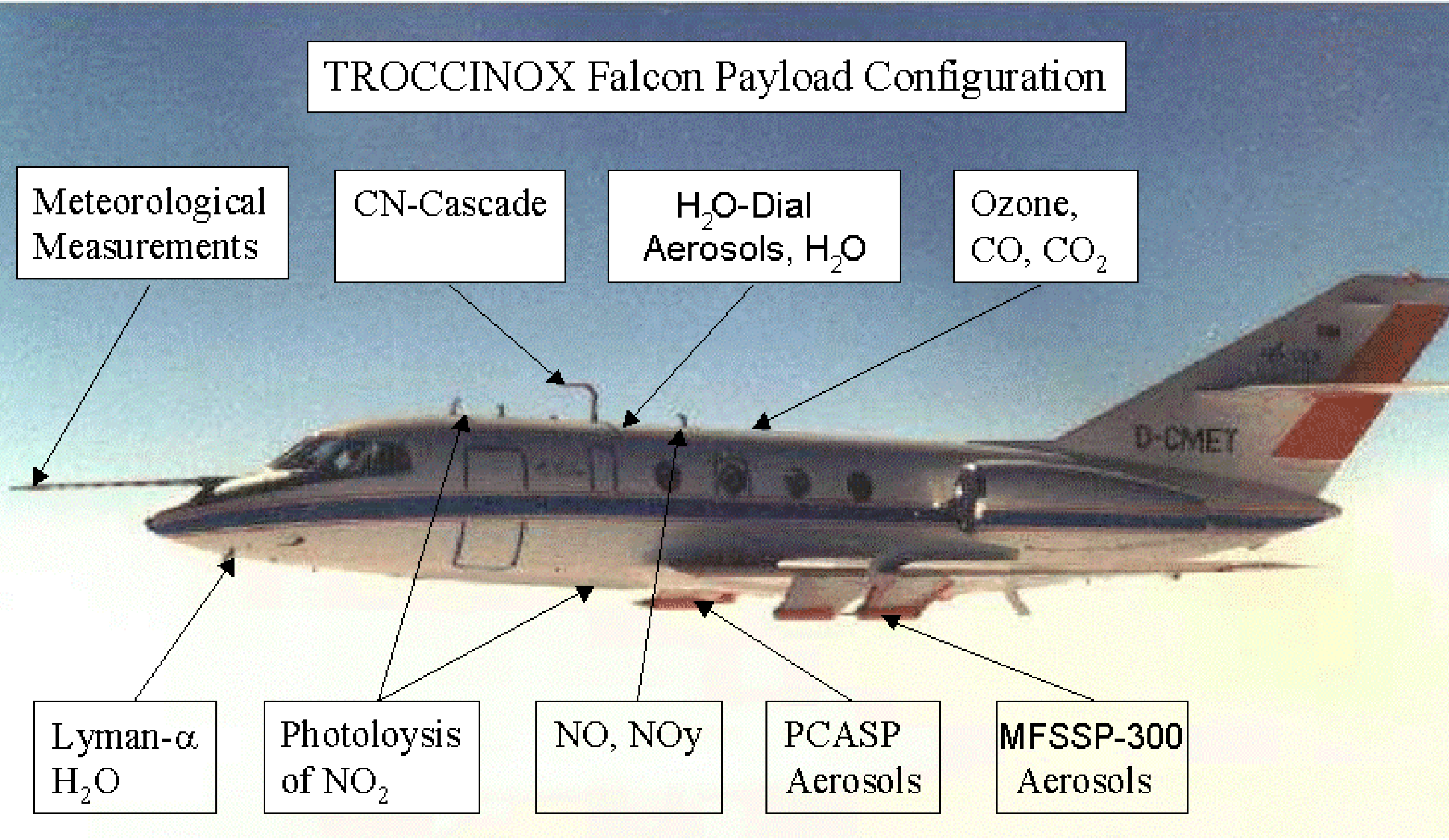
2004

First Field Experiment February-March 2004 from Gaviao Peixoto / Bauru (Sao Paulo State) with the DLR-Falcon and INPE-Bandeirante

2005

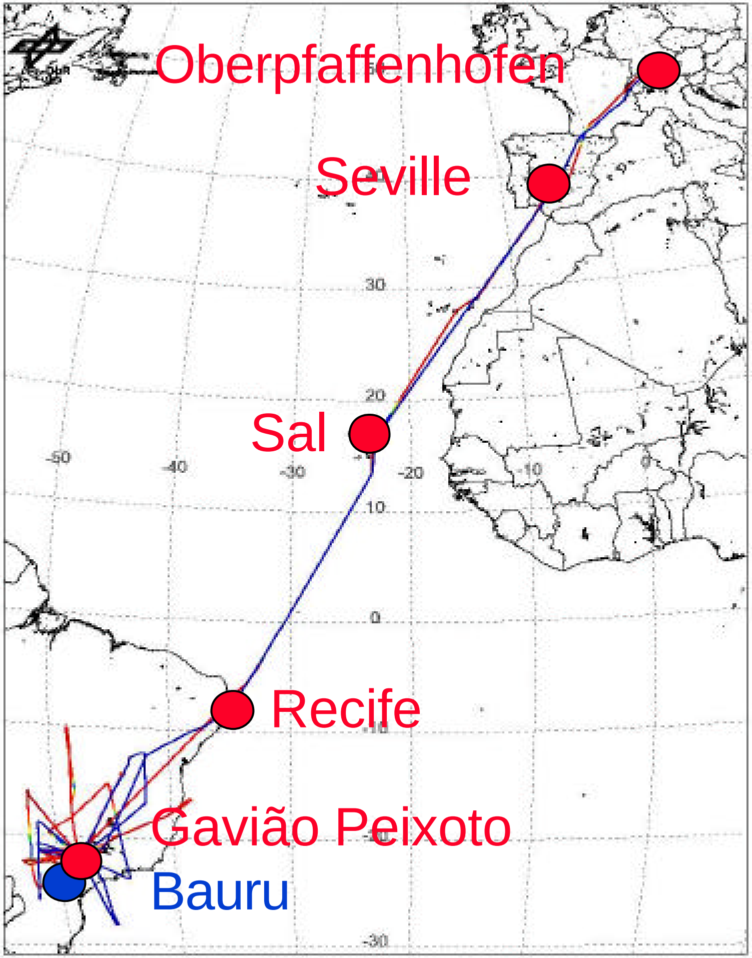
Second Field Experiment January- March 2005 with Falcon and Geophysica and Bandeirante from Araçatuba

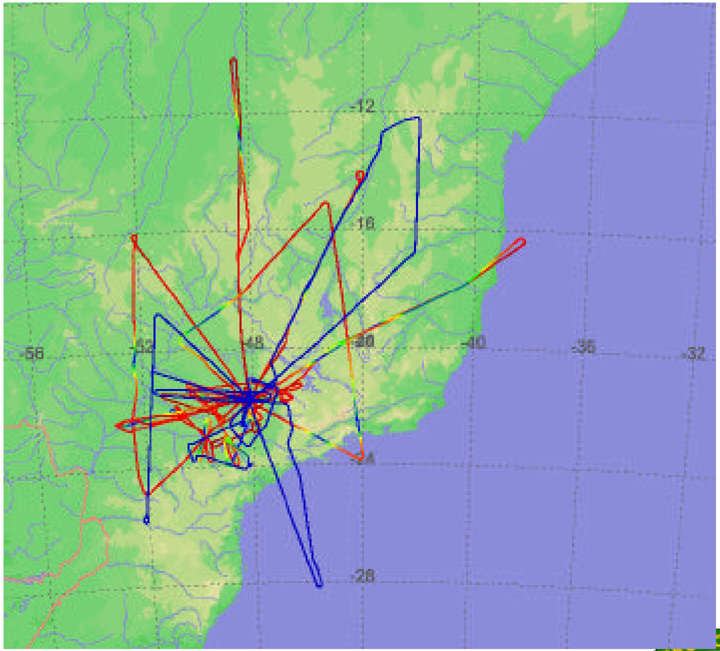
DLR-Falcon *Instrumentation*




EMBRAER
E H
D-CMET

Flight paths during transit and locally





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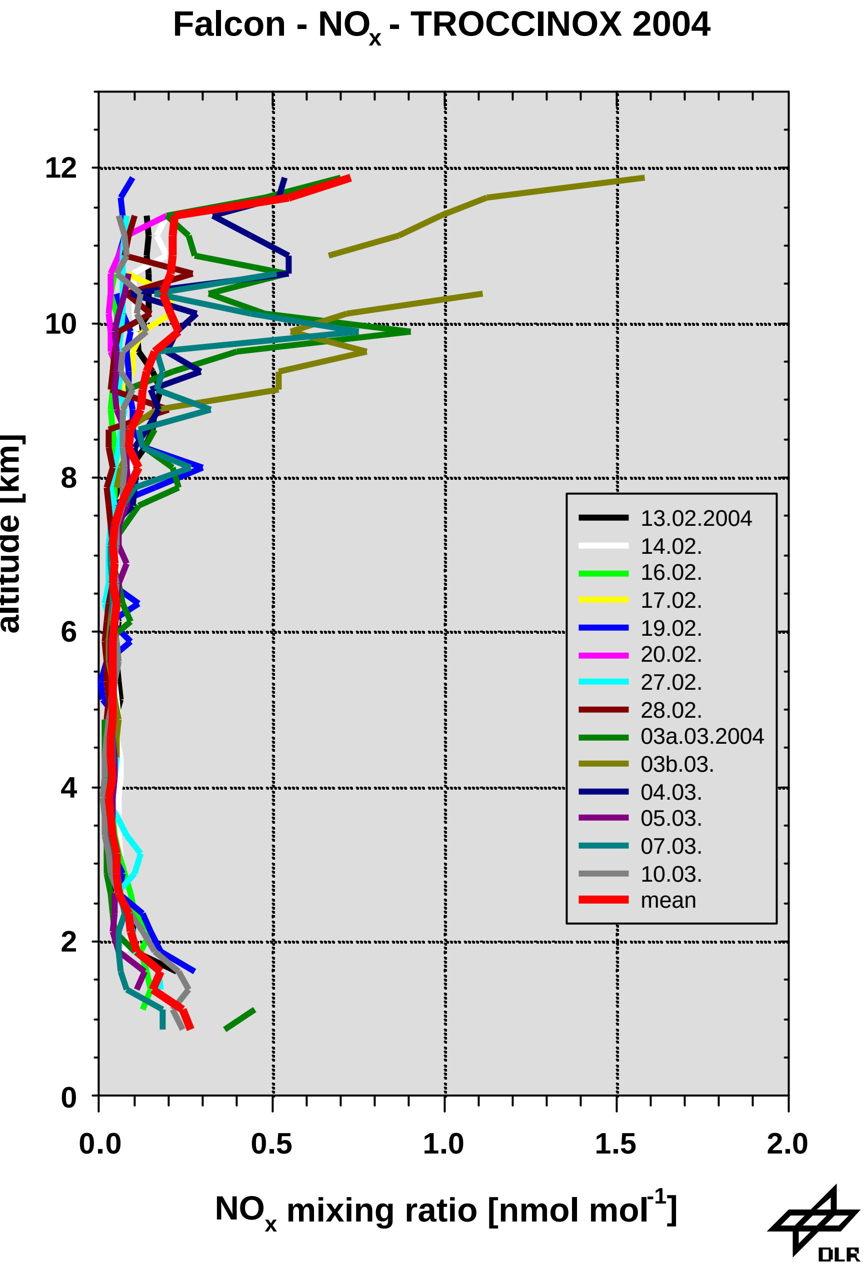
Falcon *Flights*

Date	Flight rational
3101	Transfer Oberpfaffenhofen - Seville
0202	Seville - Sal - Fernando de Naronha, Recife
0402	Recife - Gaviao Peixoto
1302	Cross-section 2: Air masses north and south of convergence zone (CZ)
1402	Radar box: Probing of thunderclouds
1602	Radar box: Air masses unaffected by convection, Comparison with HIBISCUS SP1 balloon
1702	Cross-section 4: Contrast of air masses affected / unaffected by previous tropical convection
1902	Cross-section 2: Contrast of air masses affected / unaffected by previous tropical convection
2002	N-E - triangle: Contrast of air masses affected / unaffected by tropical convection, coordinated with Bandeirante
2702	Stacked profile radar box: Comparison with HIBISCUS MIR-SAOZ balloon, and with Bandeirante
2802	Radar box: Probing of isolated thunderclouds coordinated with Bandeirante
0303a	N-W - triangle: Probing of air masses affected by previous tropical convection
0303b	Radar box: Probing of thunderclouds
0403	N- E-triangle: Lagrangian-Experiment: 2^{nd} probing of air masses measured on 0303b
0503	Profile in radar box: Air masses unaffected by convection
0703	ENVISAT validation, Constant level and profile through MIPAS limb and SCIA limb/nadir measurements
1003	Test flight before transfer to Germany and GLAS comparison
1203	Gaviao Peixoto - Recife
1403	Recife - Sal - Seville
1503	Seville - Oberpfaffenhofen

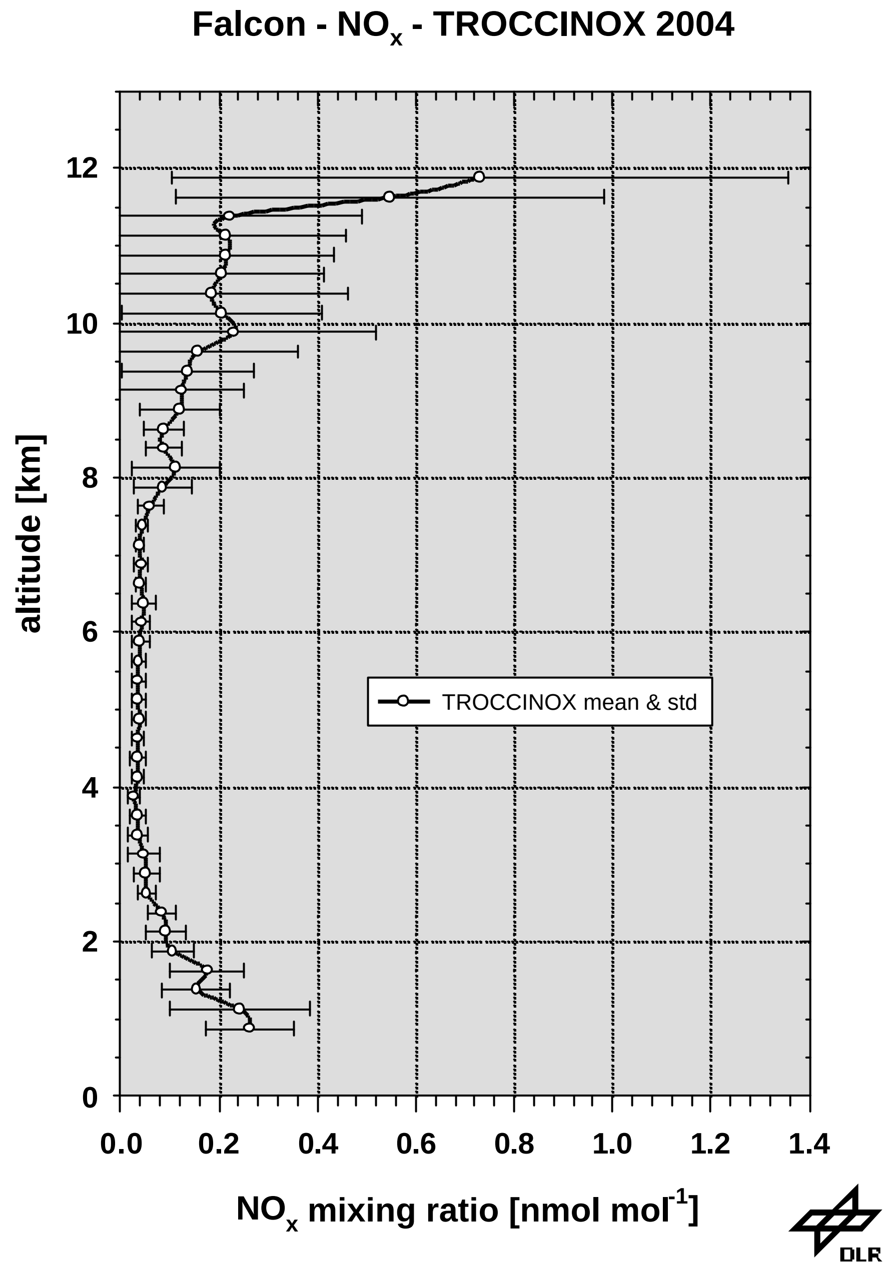
Total of 23 Falcon flights, 45 days, 82 flight hours

Some Results

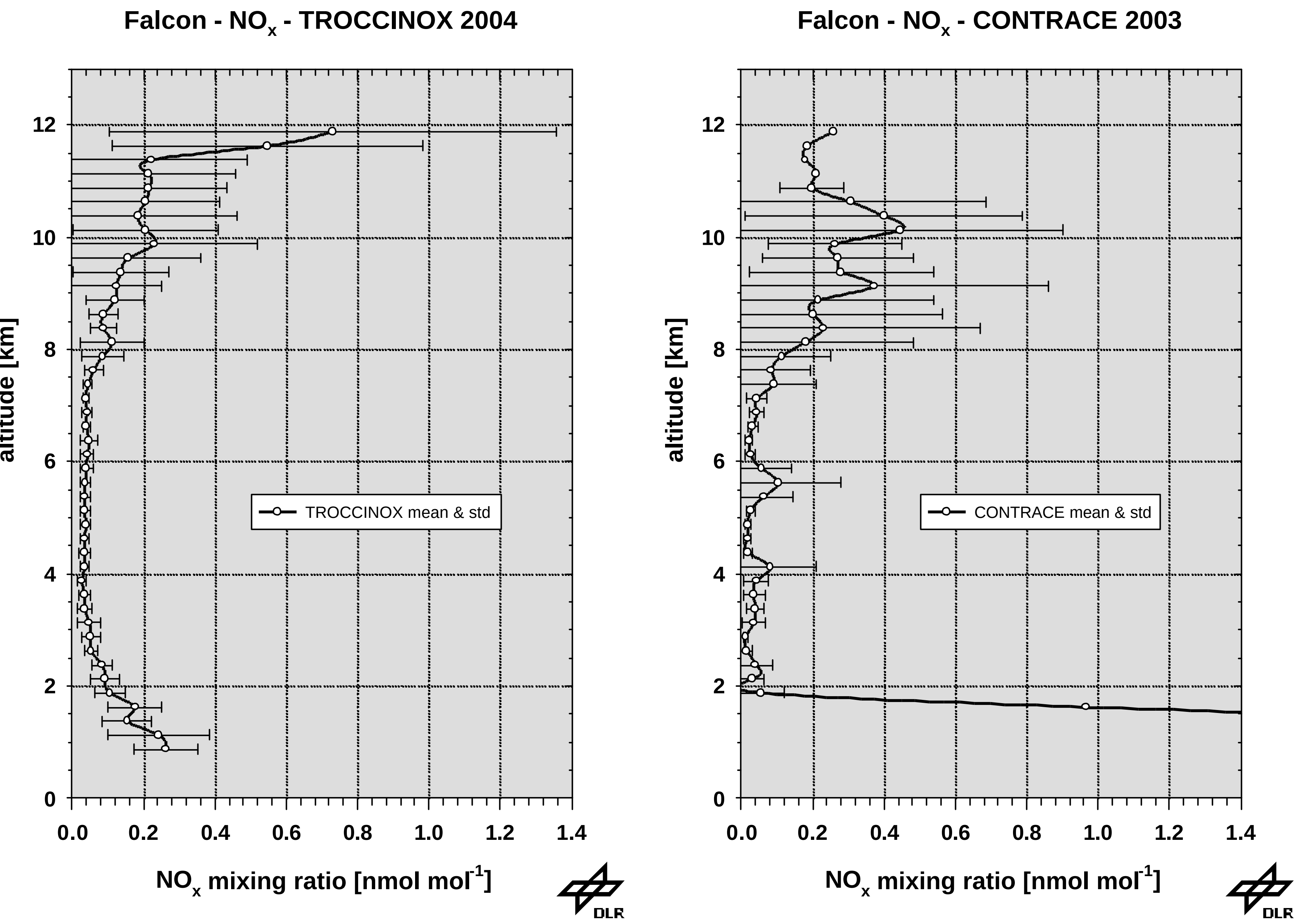
- Falcon data are evaluated and in the data bank
- Lighting NOx
- Water Vapour from Lidar
- Aerosols Loading
- Validation of Weather Predictions

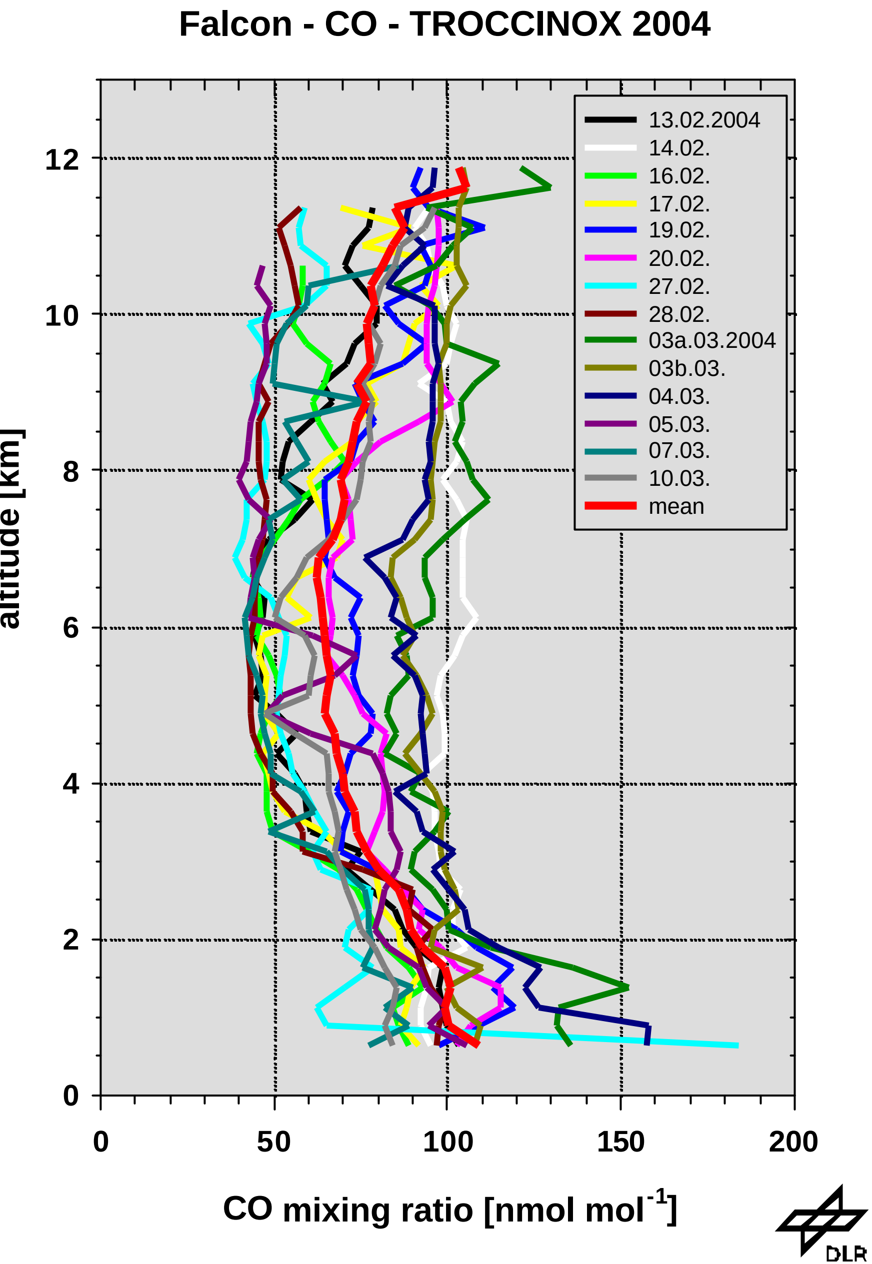


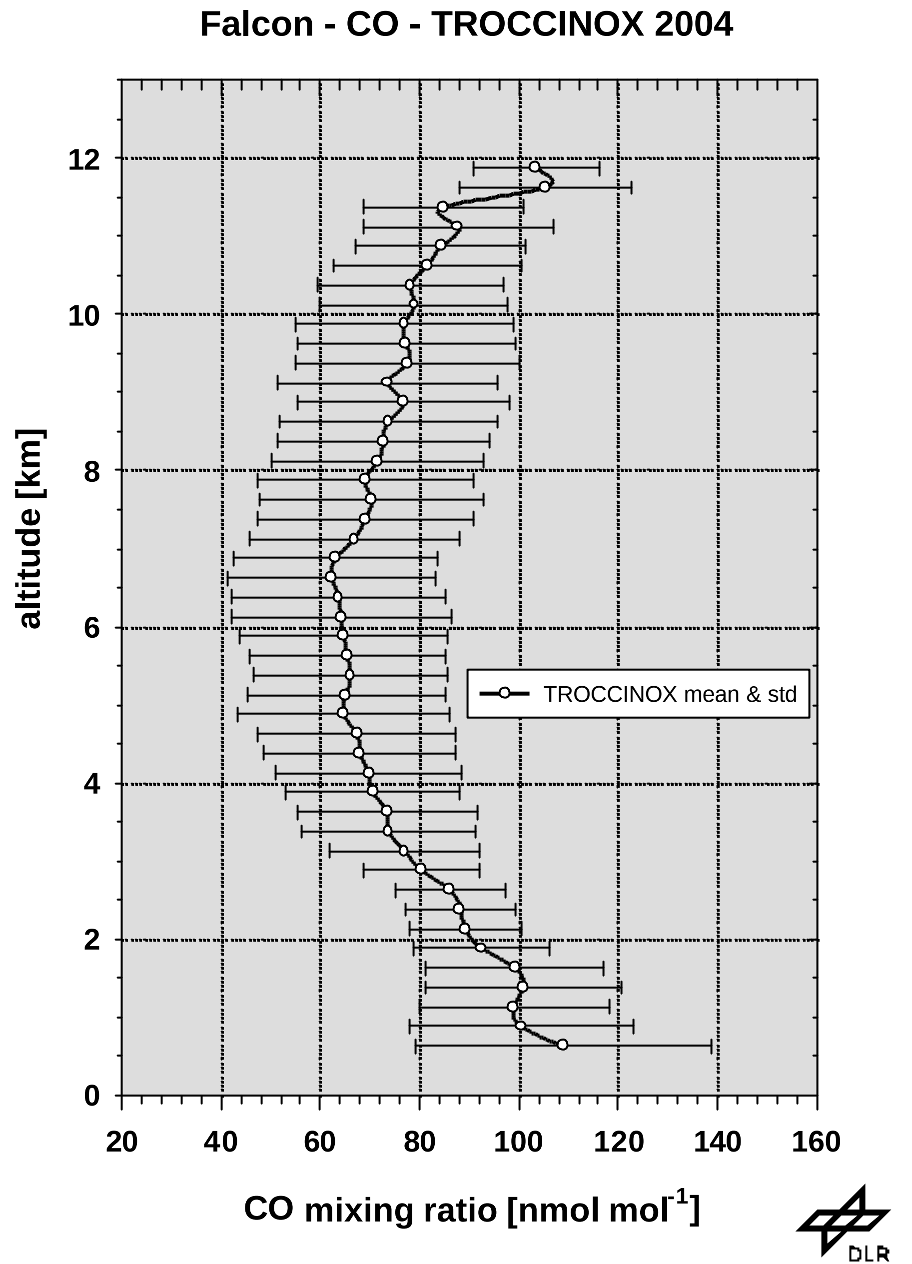
Falcon - NO_x - TROCCINOX 2004
altitude [km]
NO_x mixing ratio [nmol mol^{-1}]
13.02.2004
14.02.
16.02.
17.02.
19.02.
20.02.
27.02.
28.02.
03a.03.2004
03b.03.
04.03.
05.03.
07.03.
10.03.
mean
DLR

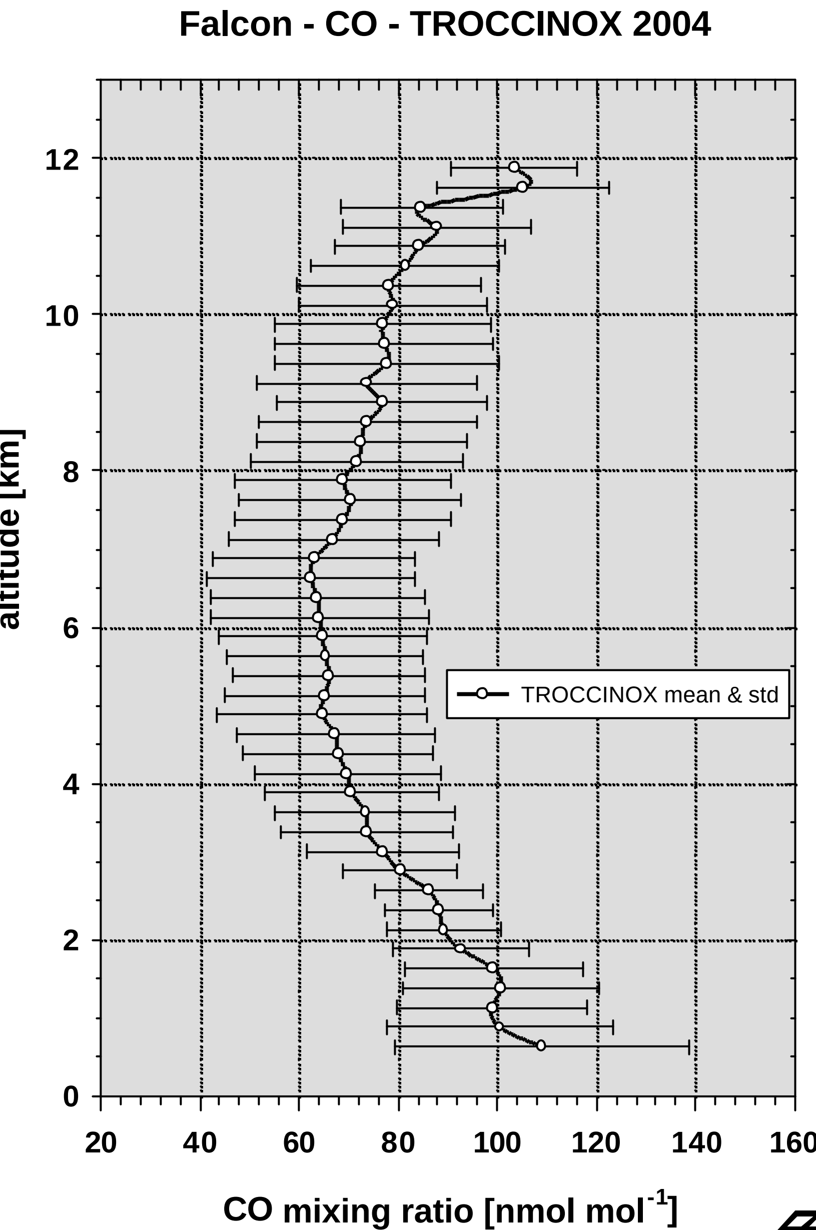


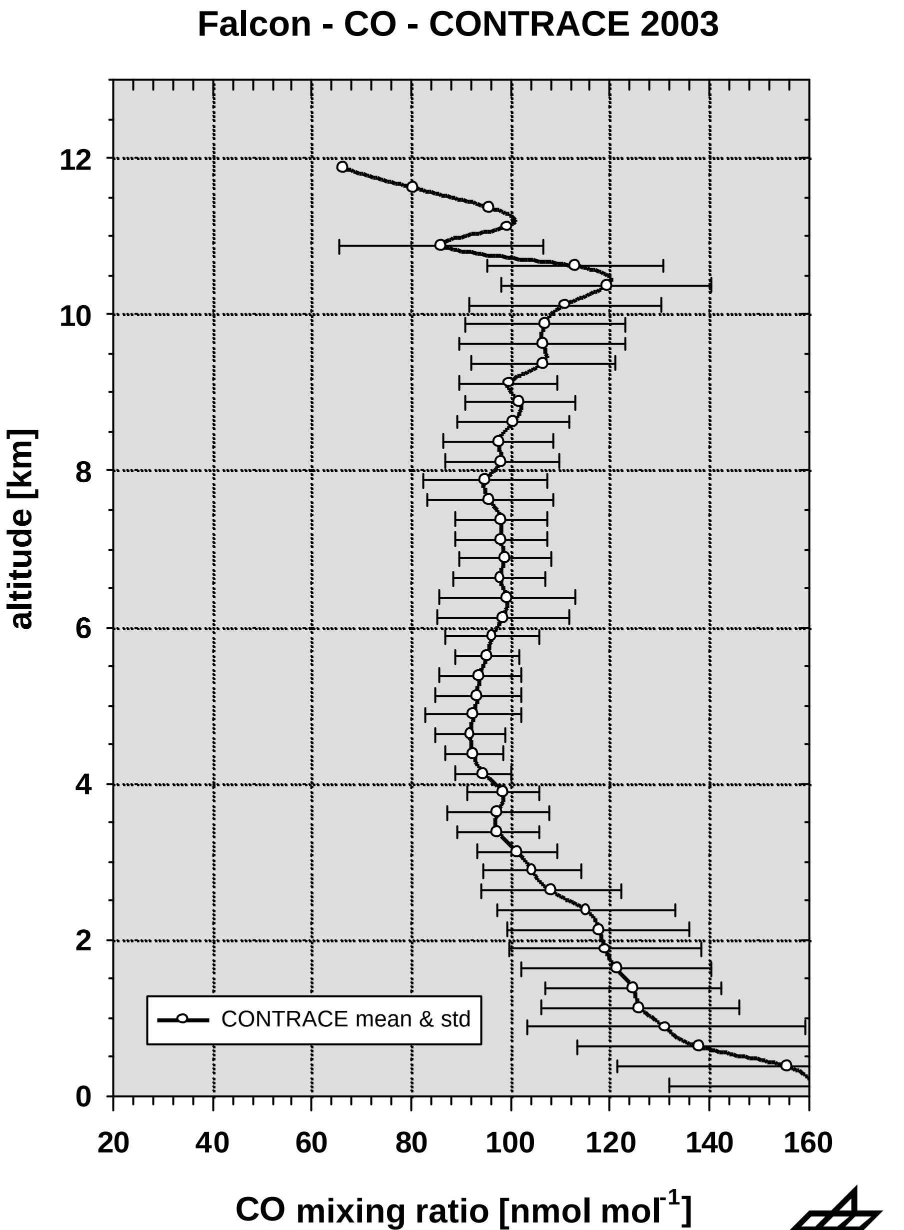
Falcon - NO_x - TROCCINOX 2004
altitude [km]
NO_x mixing ratio [nmol mol^{-1}]
TROCCINOX mean & std
DLR


Falcon - NO_x - TROCCINOX 2004
altitude [km]
TROCCINOX mean & std
NO_x mixing ratio [nmol mol^{-1}]
DLR
Falcon - NO_x - CONTRACE 2003
altitude [km]
CONTRACE mean & std
NO_x mixing ratio [nmol mol^{-1}]
DLR

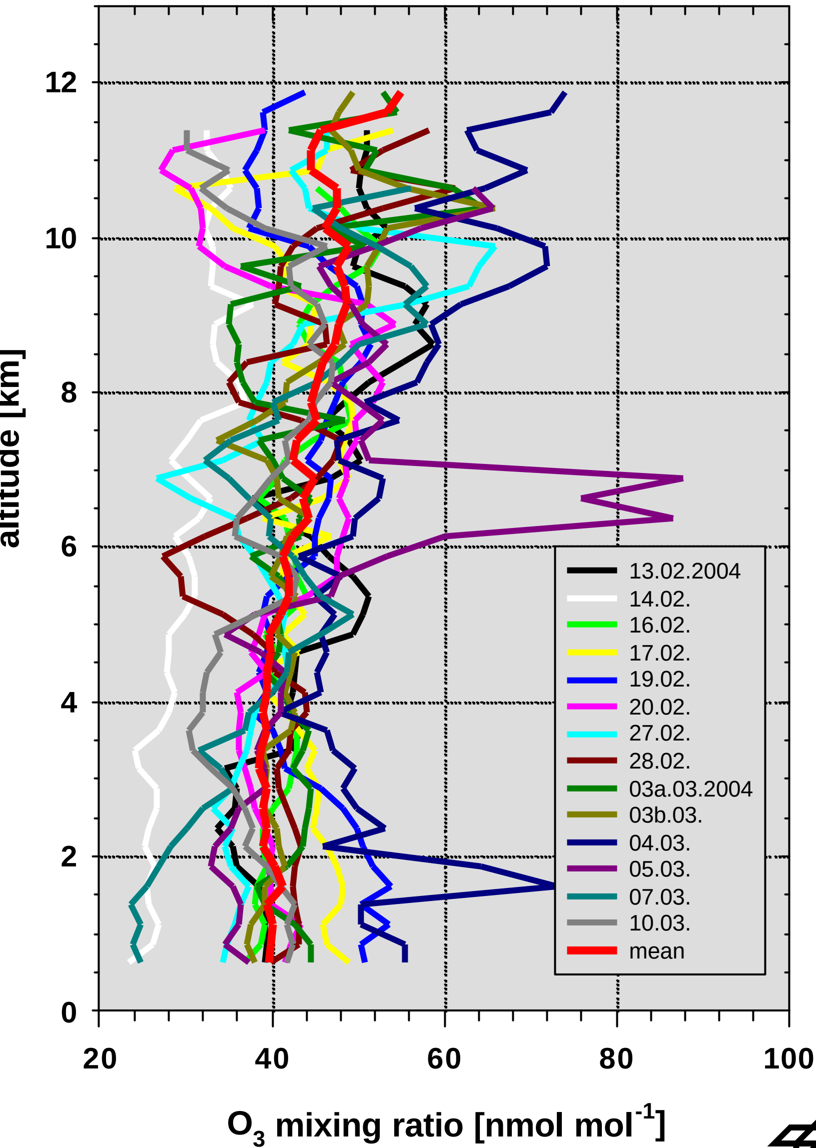

Falcon - CO - TROCCINOX 2004
altitude [km]
CO mixing ratio [nmol mol-1]
13.02.2004
14.02.
16.02.
17.02.
19.02.
20.02.
27.02.
28.02.
03a.03.2004
03b.03.
04.03.
05.03.
07.03.
10.03.
mean
DLR


Falcon - CO - TROCCINOX 2004
altitude [km]
CO mixing ratio [nmol mol-1]
TROCCINOX mean & std
DLR

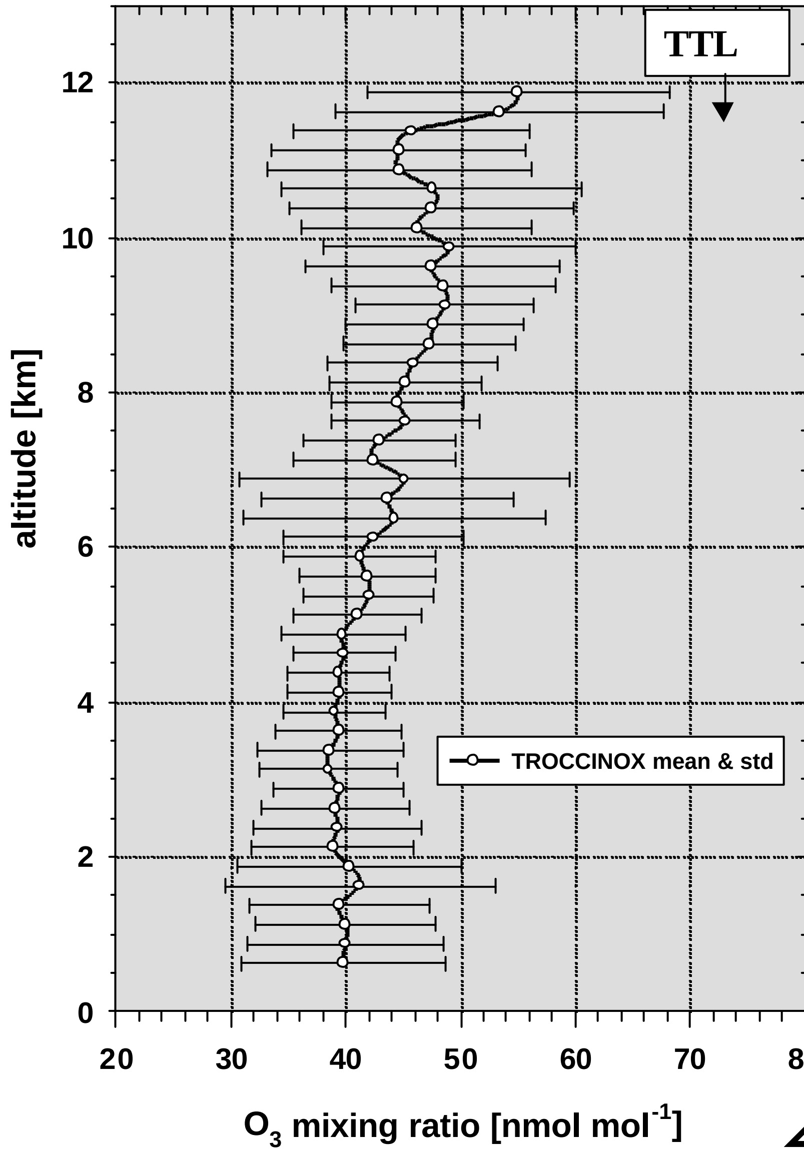

Falcon - CO - TROCCINOX 2004
altitude [km]
CO mixing ratio [nmol mol-1]
TROCCINOX mean & std
0
2
4
6
8
10
12
20
40
60
80
100
120
140
160


Falcon - CO - CONTRACE 2003
altitude [km]
CO mixing ratio [nmol mol-1]
CONTRACE mean & std
0
2
4
6
8
10
12
20
40
60
80
100
120
140
160

Falcon - O_3 - TROCCINOX 2004



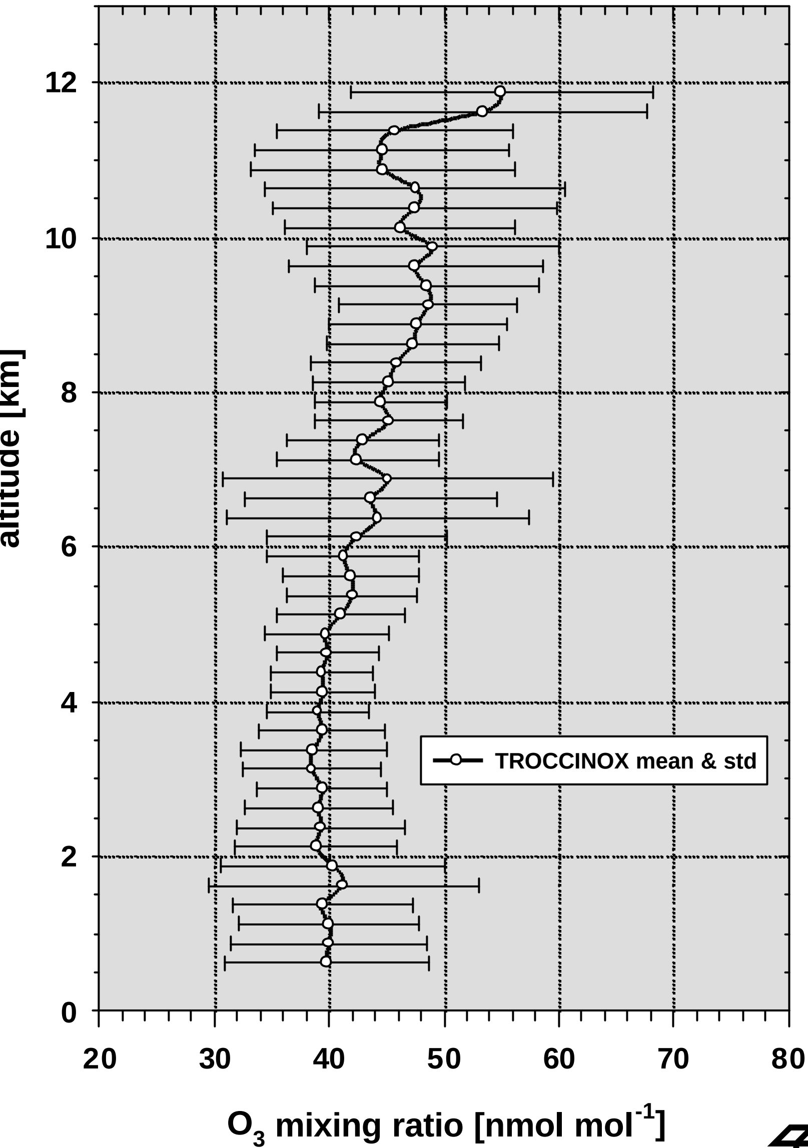
Falcon - O_3 - TROCCINOX 2004



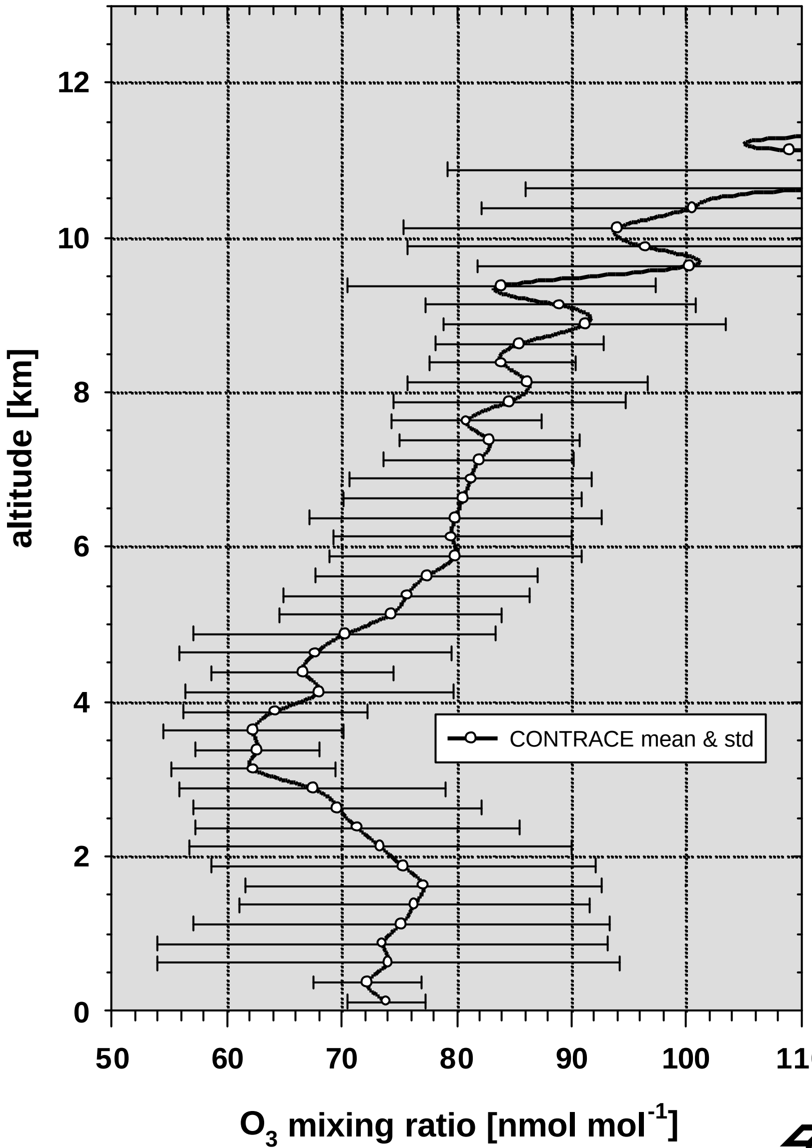
DLR

DLR

Falcon - O_3 - TROCCINOX 2004



Falcon - O_3 - CONTRACE 2003



different scale!

1. Method to estimate lightning-produced NO_x

$P(NO_X) = [NO_X]\, F_C\, S\, C$:

global annual NO_X production rate (g(N) yr^{-1})

$[NO_X]$: the average volume mixing ratio in the anvil produced by lightning (nmol/mol)

$F_C = (V_a - V_s)\ \rho_a\, \Delta x\, \Delta z$:

average rate at which air is advected out of the anvil (g(air) s^{-1} $anvil^{-1}$)

S: number of active cumulonimbus cells occurring at any instant globally (ca. 2000)

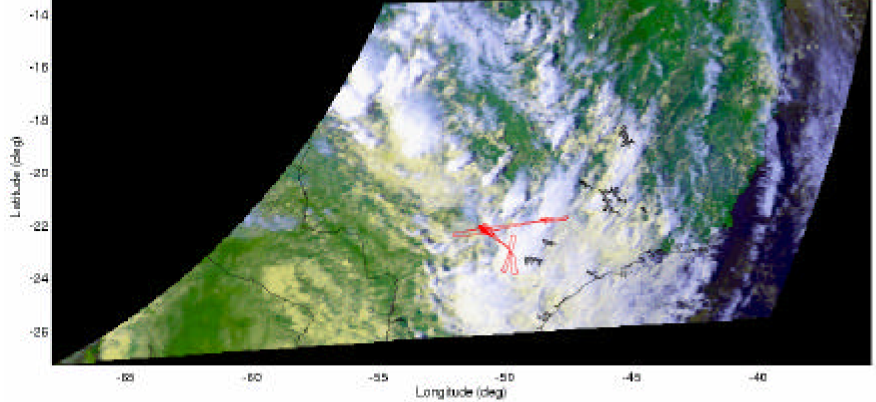
C: conversion factor (g(N) $g(air)^{-1}$ s yr^{-1})

[Chameides et al., JGR, 1987; Huntrieser et al., JGR, 2002]

Lightning NOx,

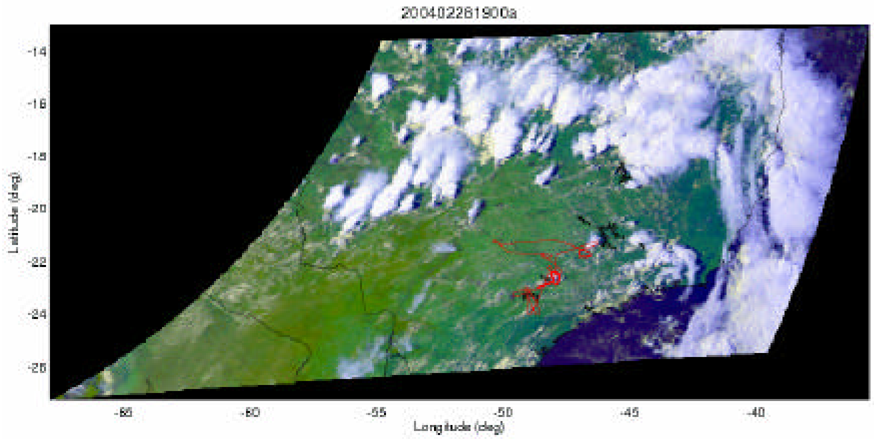
Case studies for

3 Thunderstorms



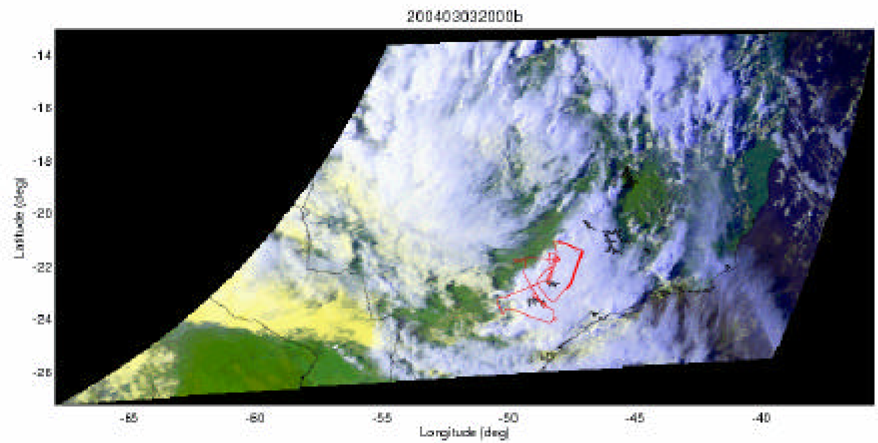
Feb 14

-70°C, 14.5 k



Feb 28

-50°C, 11.5 k



March

-80°C, 16 km

MSG, Ch1, 2, 9:
RGB Composite from channels
at 0.6mm, 0.8 mm and 10.8 mm

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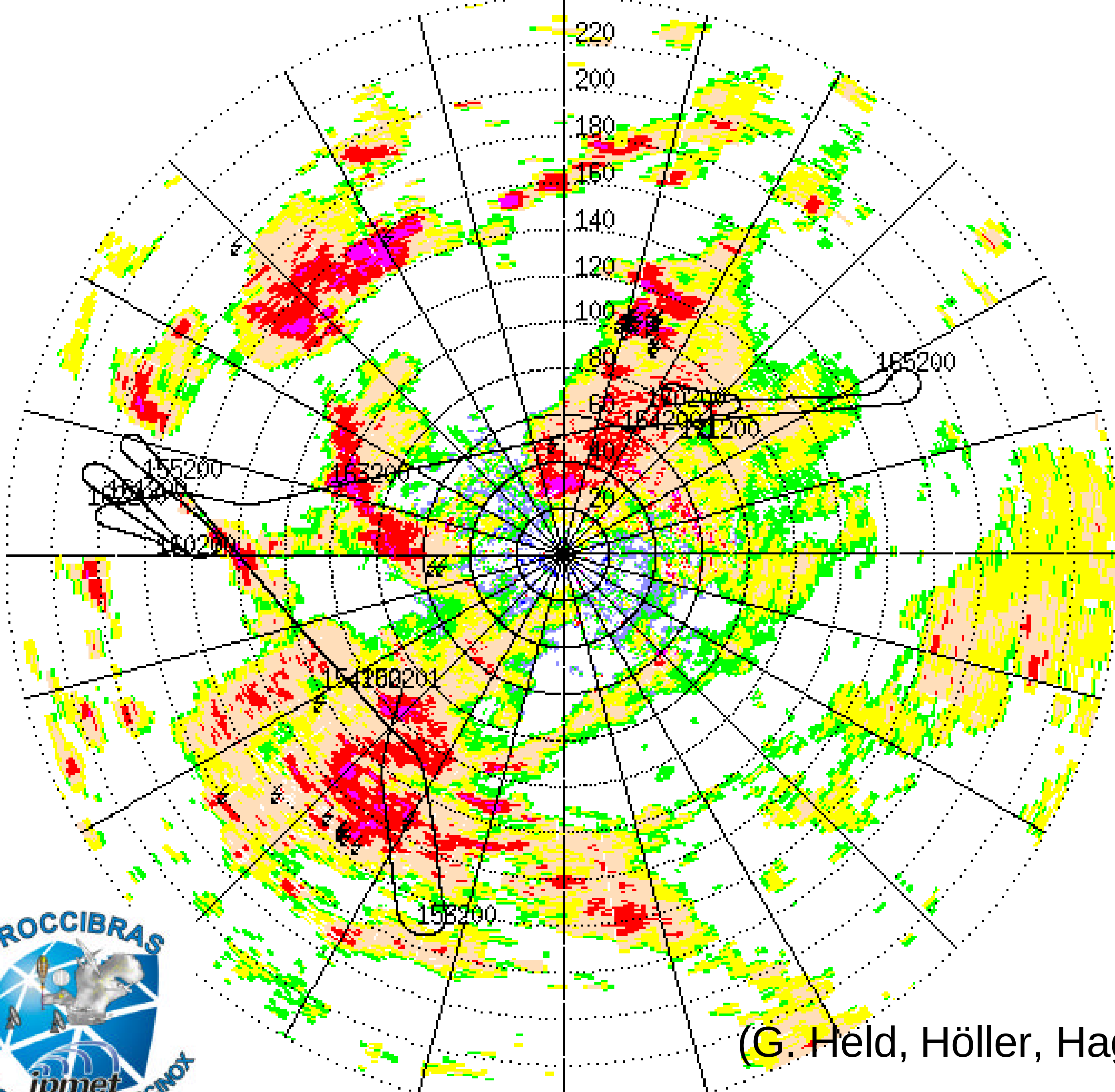
14 Febr



IPMET, Baur
Radar 1523L
Reflectivity

+

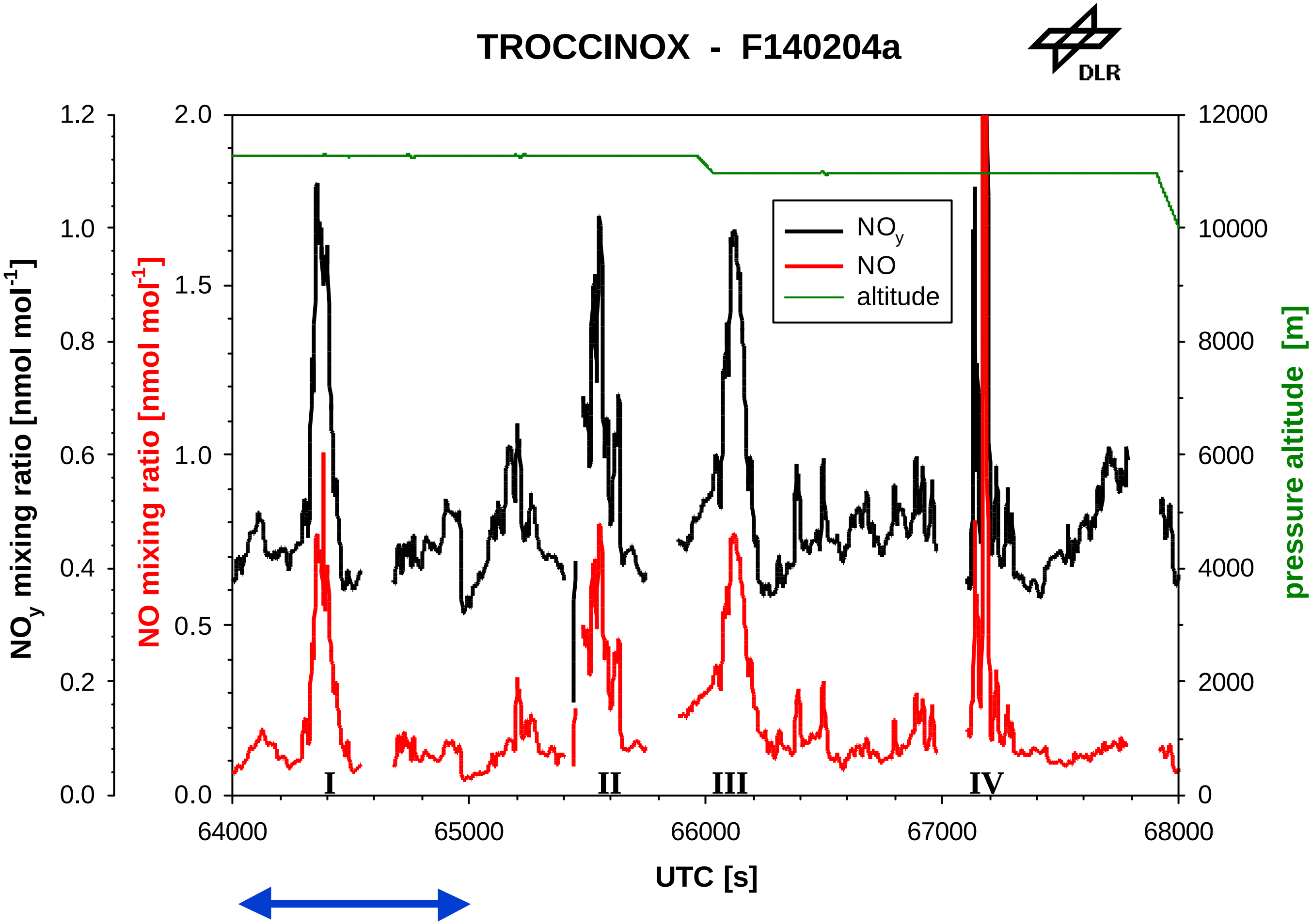
Lightning
(IRAS) 1500
1530LT

+

Falcon path
(time LT)

(G. Held, Höller, Hagen, 2004)

NOx in Thunderstorms, 14.02.04



~200 km

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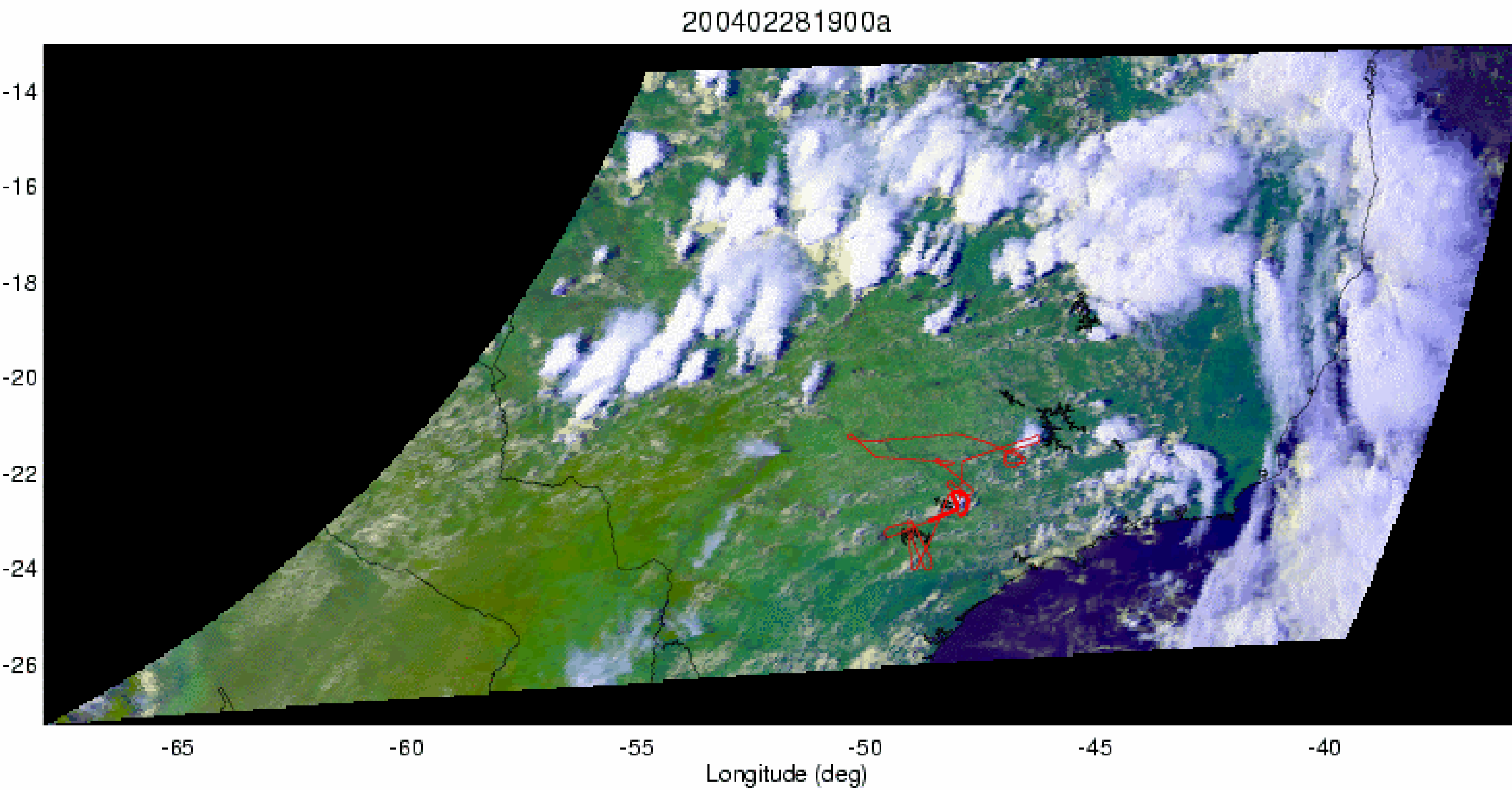
28 February



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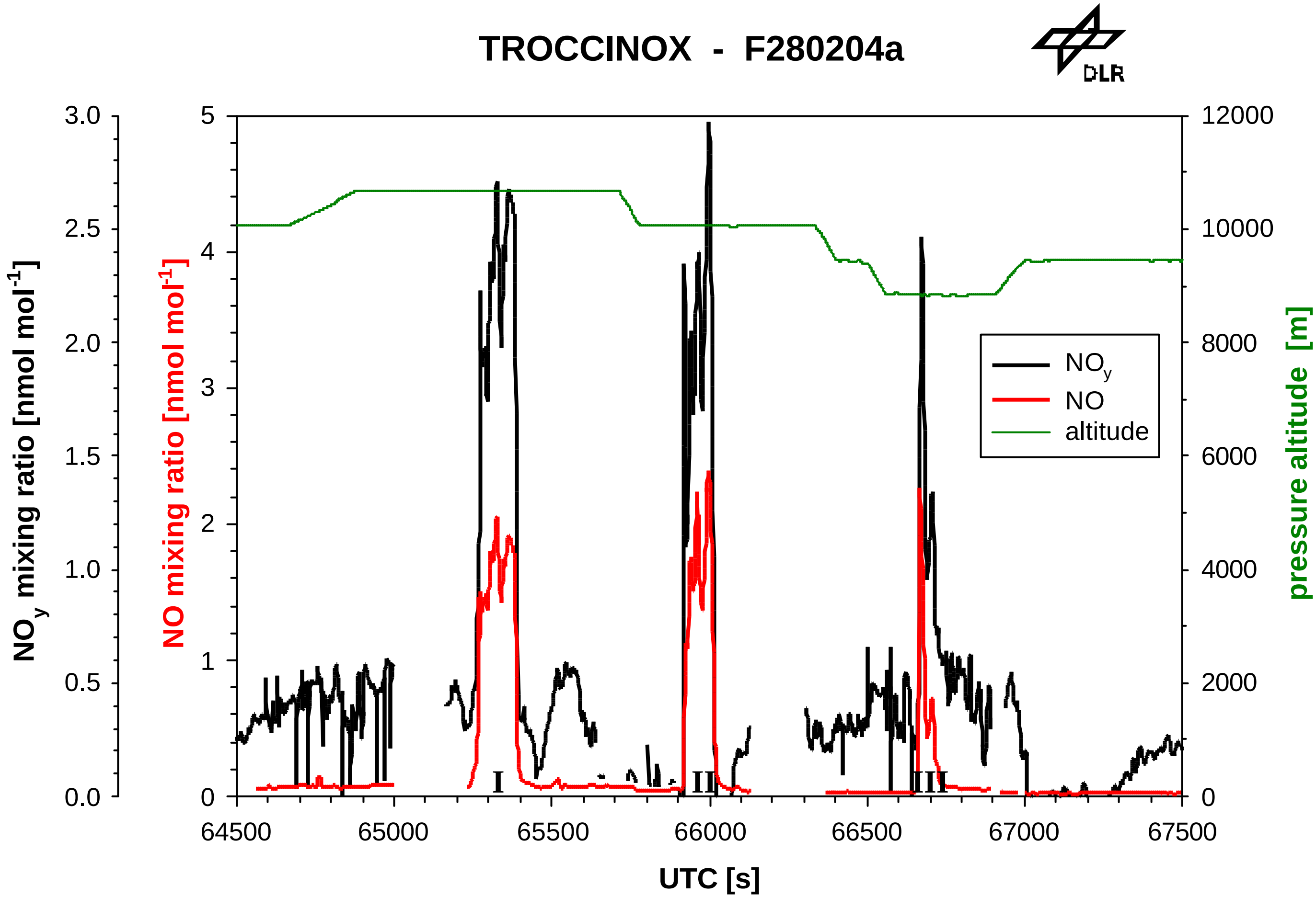
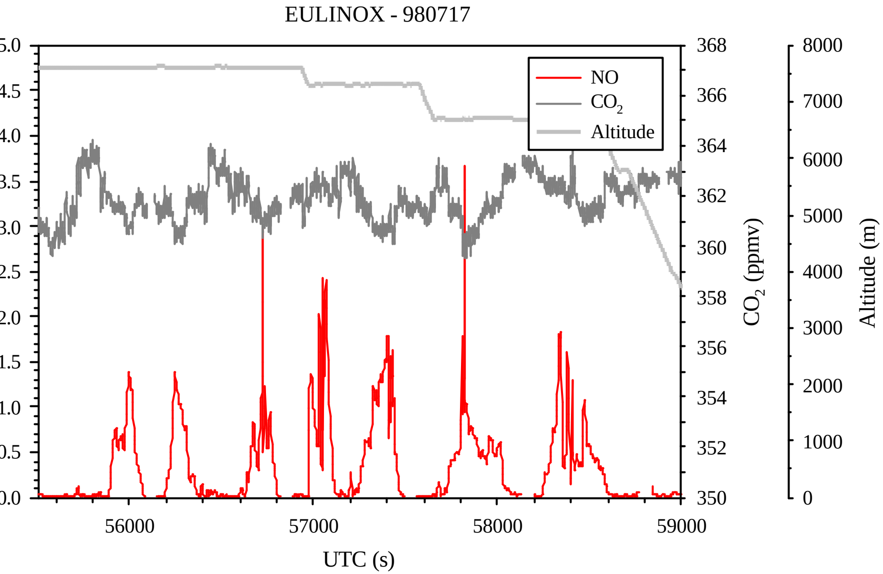
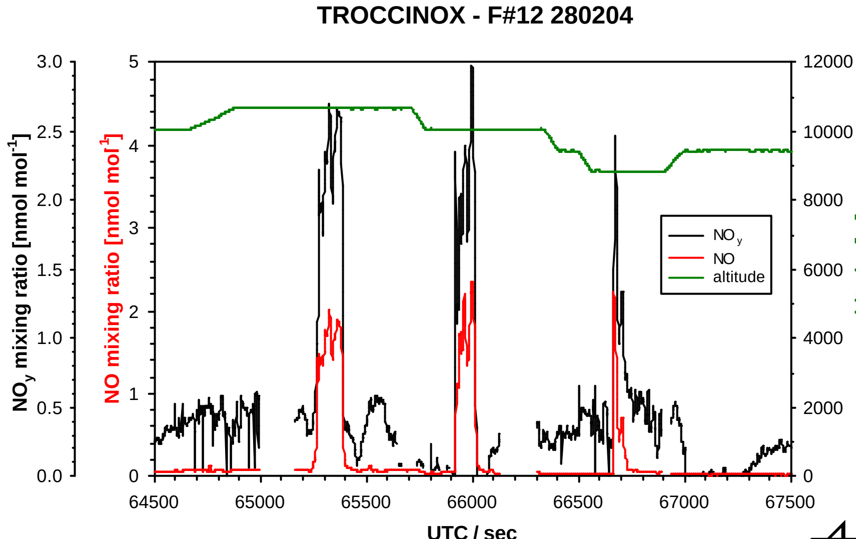
NOx in Thunderstorms, 28.02.04

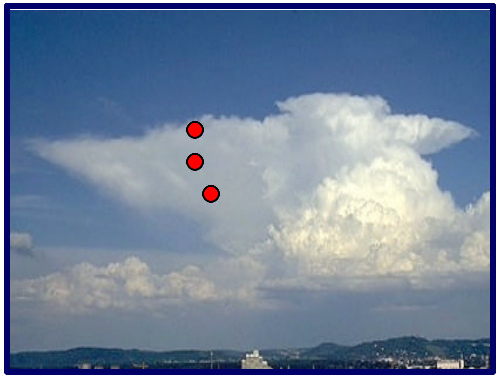


Comparison EULINOX/TROCCINOX thunderstorms:

28 February 2004 case







Similar width (20-40 km) and height (1-2 nmol mol^{-1}) of NO signatures in the anvil outflow

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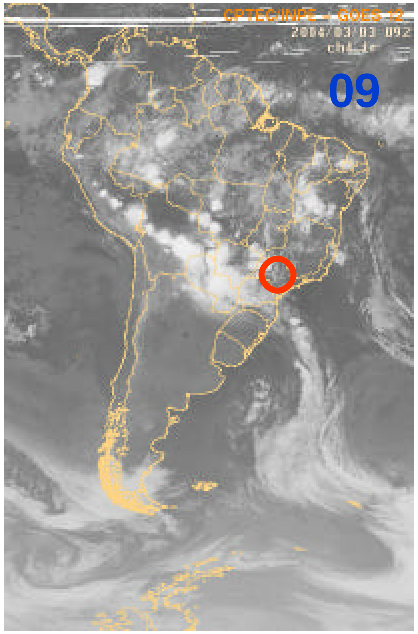
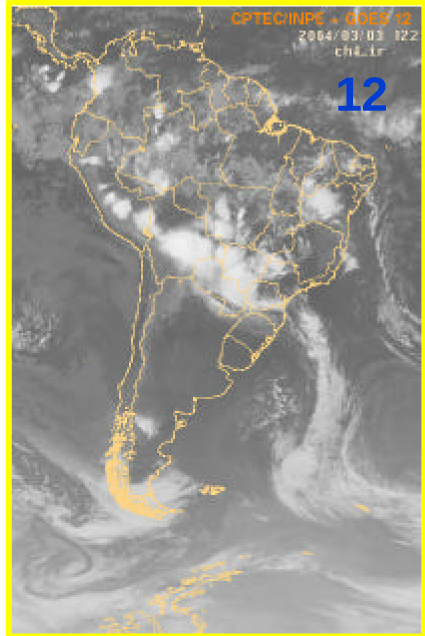
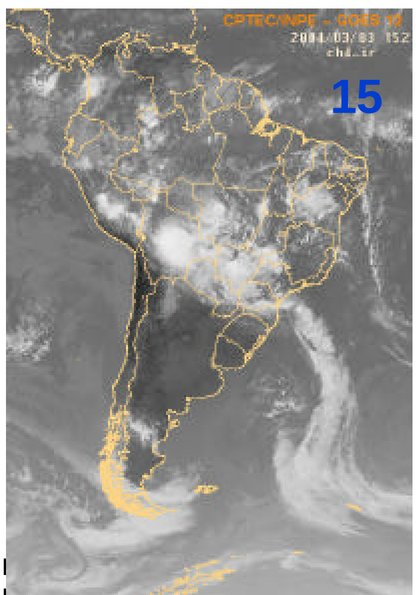
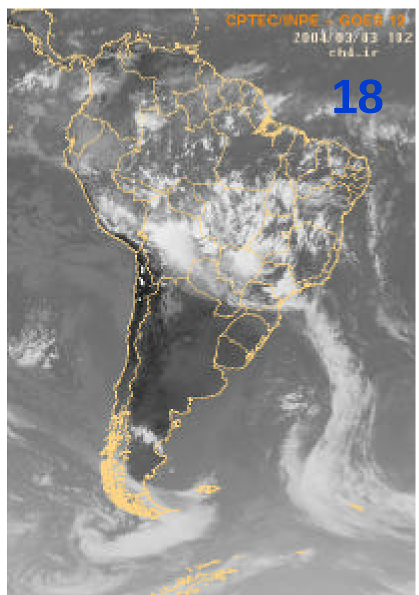
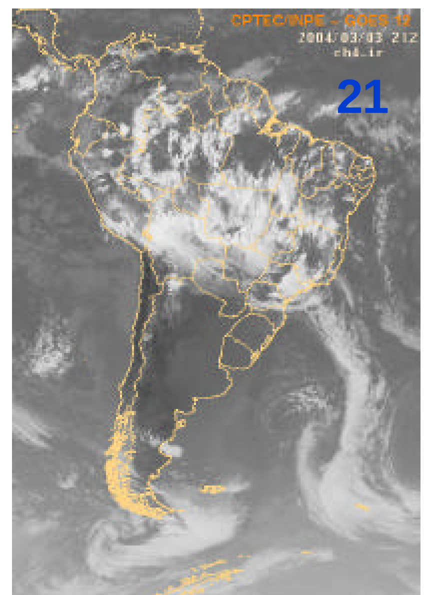
Development of deep convection on 3 March



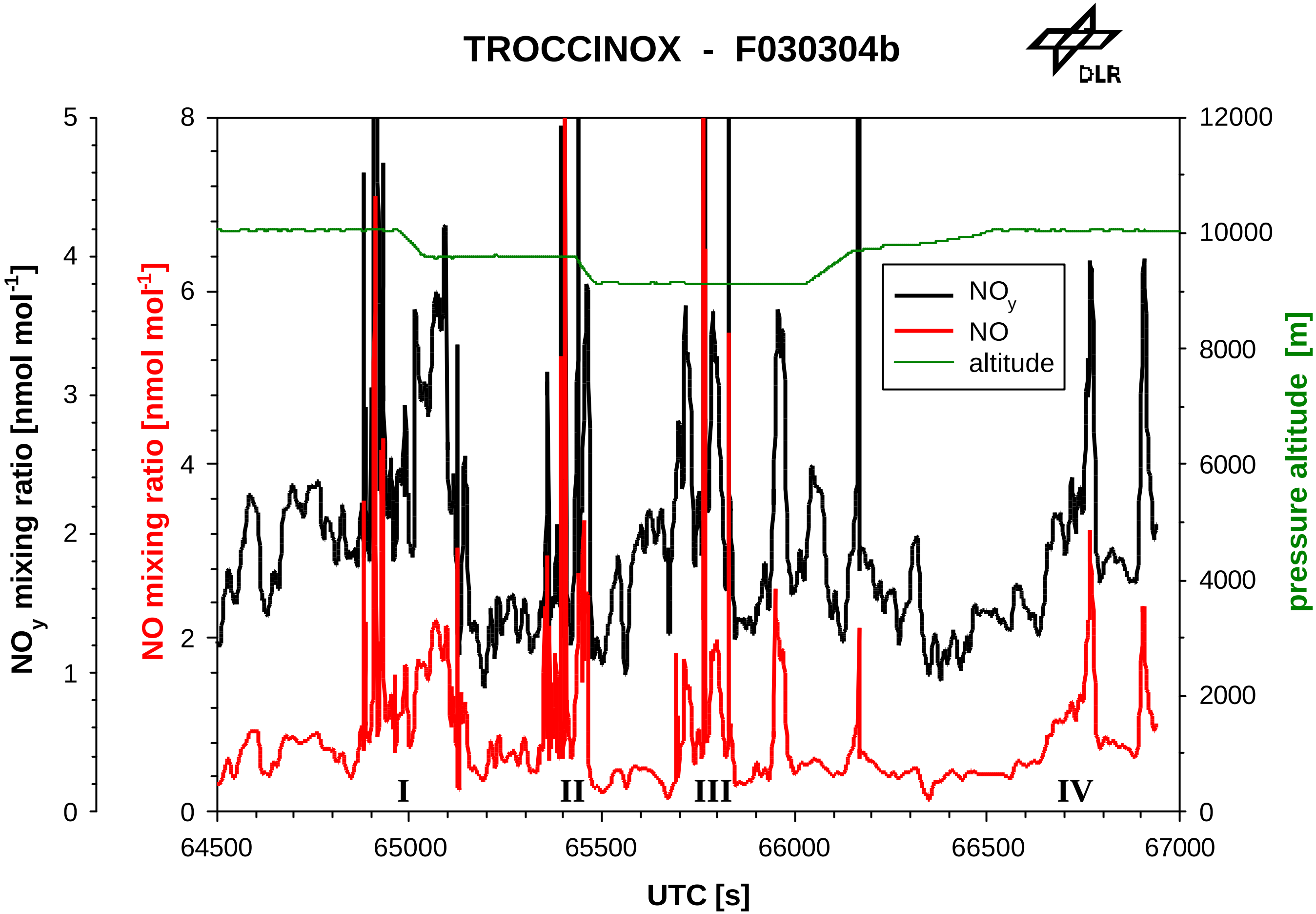




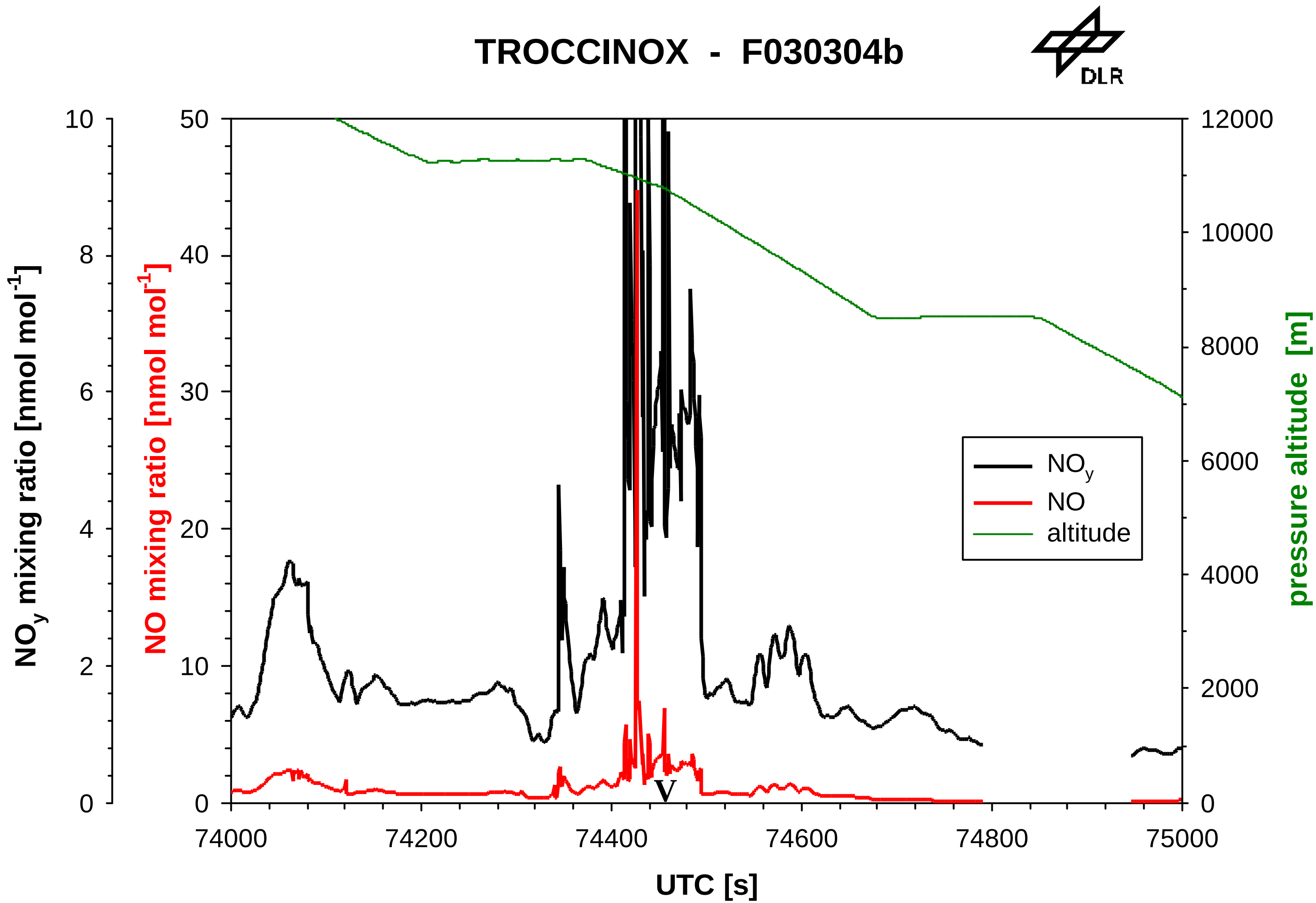




NOx in Thunderstorms, 03.03.04, Part 1



NOx in Thunderstorms, 03.03.04, Part 2



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Method to estimate lightning-produced NO_x

$P(NO_x) = [NO_x]\, F_c\, S\, C$ **:**

global annual NO_x production rate (g(N) yr^{-1})

$[NO_x]$: **the average volume mixing ratio in the anvil produced by lightning (nmol/mol)**

$F_c = (V_a - V_s)\ r_a\ Dx\ Dz$**:**

average rate at which air is advected out of the anvil (g(air) s^{-1} $anvil^{-1}$)

***S*:** **number of active cumulonimbus cells occurring at any instant globally (ca. 2000)**

***C*:** **conversion factor (g(N) $g(air)^{-1}$ s yr^{-1})**

[Chameides et al., JGR, 1987; Huntrieser et al., JGR, 2002]

Parameters of Observed Convective Events during TROCCINOX and Comparison to European Cases

	TROCCINOX			LINOX/EULINOX	
ase	140204	280204	030304b	medium	large
oud top, km	14.5	11.5	16		
ight altitude, km	11-11.3	8.8-10.7	9.1-10		
O_{max}, nmol/mol	3.2	2.4	45	2.6	3.8
O_{xm}, nmol/mol	0.5	1.3	1.9	1.3	2.2
$O_{x,inflow}$, nmol/mol	<0.1	<0.2	<0.2	0.5	0.5
x, km	40	25	30	30	45
z, km	1	1.9	1	1	1
$-v_s$, m s^{-1}	7	11	12	8	13
c, 10^8 kg s^{-1}	1.1	2.0	1.5	1.3	2.3
(NOx), Tg(N) yr^{-1}	1.7*	7.8	8.6*	3.1 (2-4)	11.7 (10-13)

* **Lower limit estimates,**
since only the lower part of the anvil outflow was investigated.

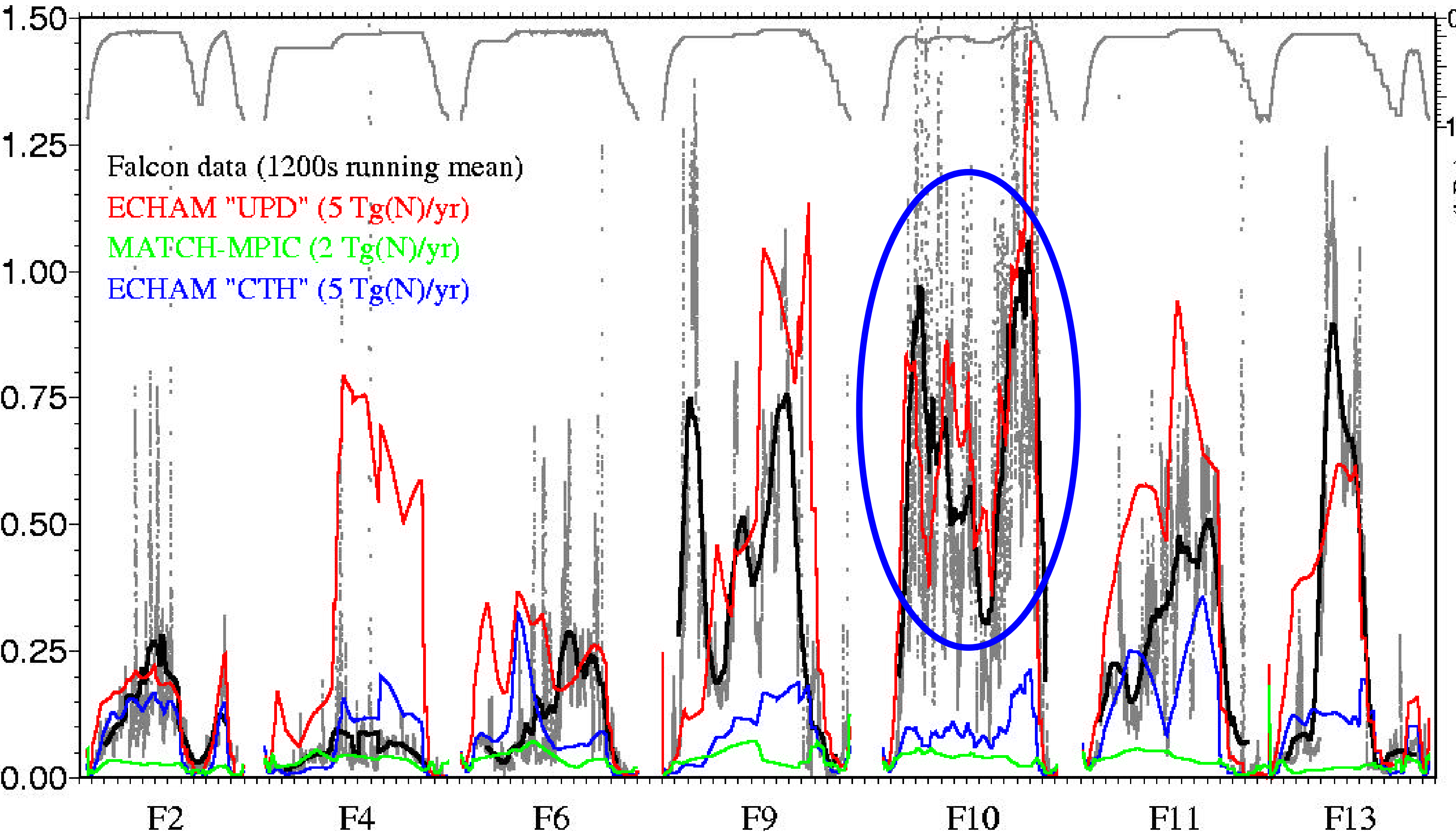
(LINOX/EULINOX from Huntrieser et al., 1998, 2002)

2. Method to estimate lightning-produced NO_x

Fit Source Strength and Profile of LNOx source rate in global chemical transport models (with meteorological fields based on weather analysis, ECMWF) to optimally fit observed NOx mesurements (and other data) in regions where the NOx concentration is mainly due to LNOx.

See presentation Huntrieser et al., later today

Measurement and Modelling of Nitrogen Oxide NO



Huntrieser, Kurz, Grewe, Lawrence, Labrador,
Schlager, Schumann et al., tbp

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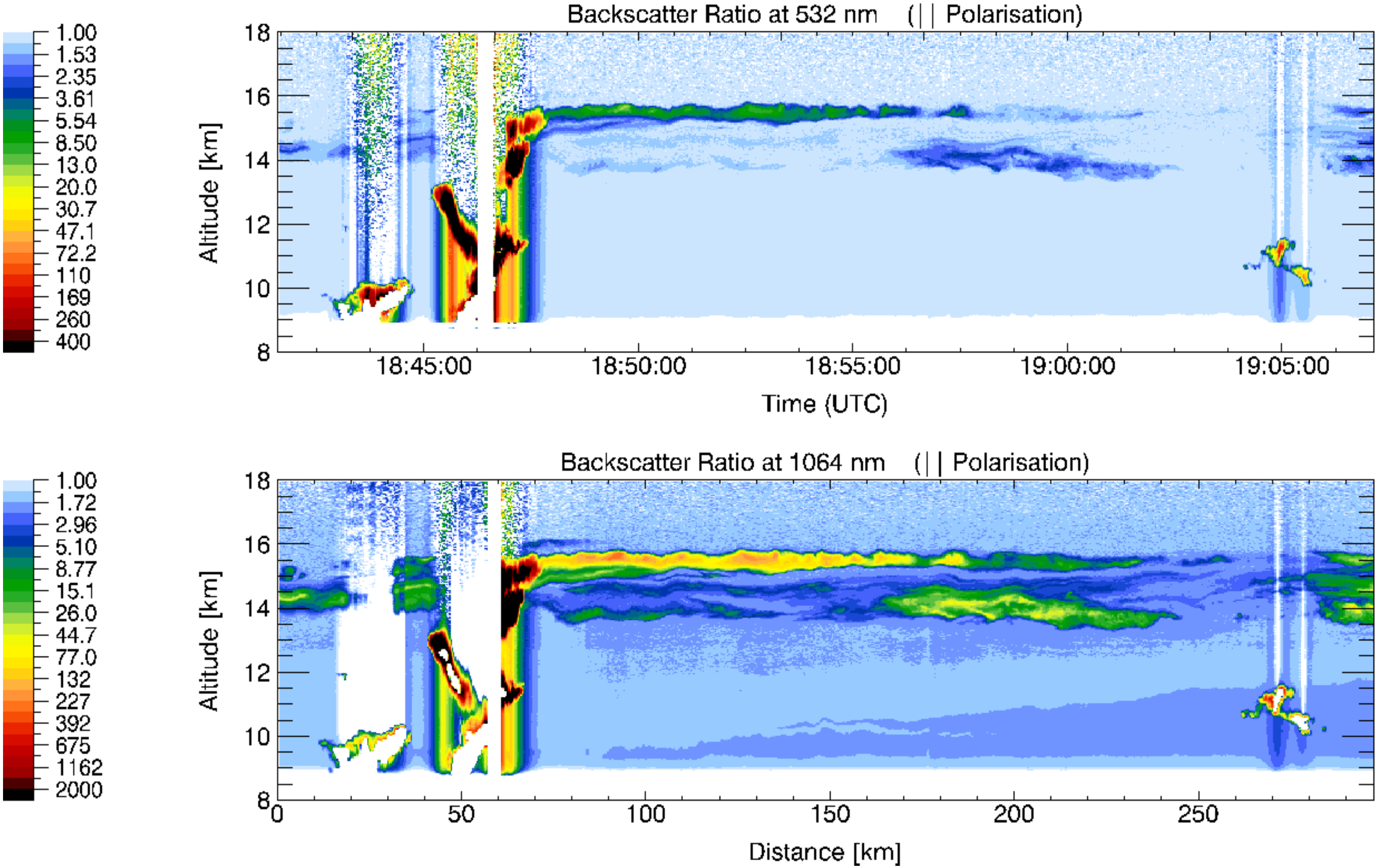
Lidar observation shows Cb-Anvil, e.g. 17 Febr. 2004



Outflow up to 15.5 km altitude: Geophysica or HALO required

(Ehret, Fix, Flentje, Wirth, et al., 2004)

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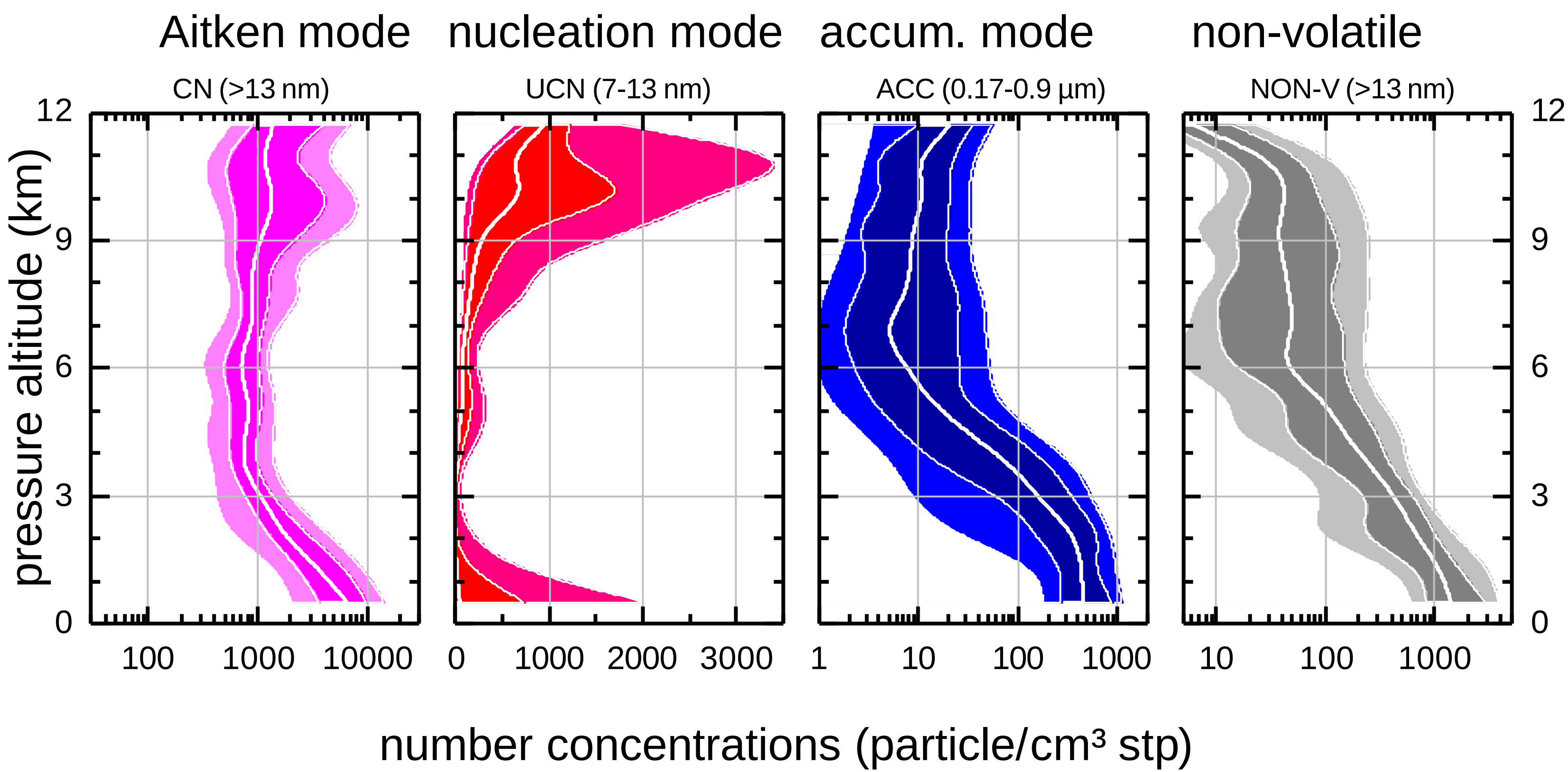
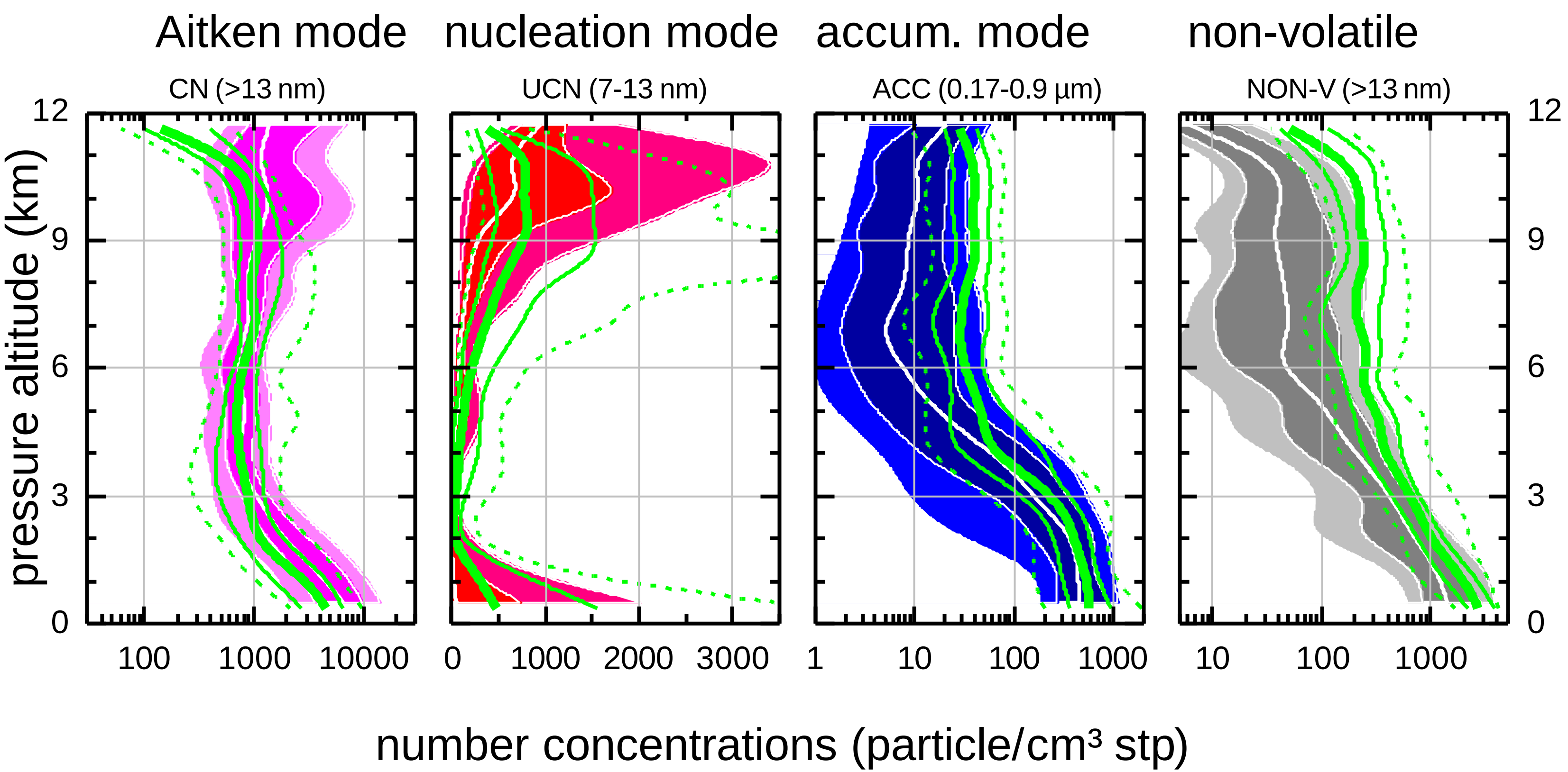
Vertical profiles of aerosol number concentrations



Statistics over all mission flights from GPX

Vertical profiles: comparison with a mid-latitude summer time continental Europe campaign



Statistics over all mission flights from GPX
& from the UFA/EXPORT campaign in 200

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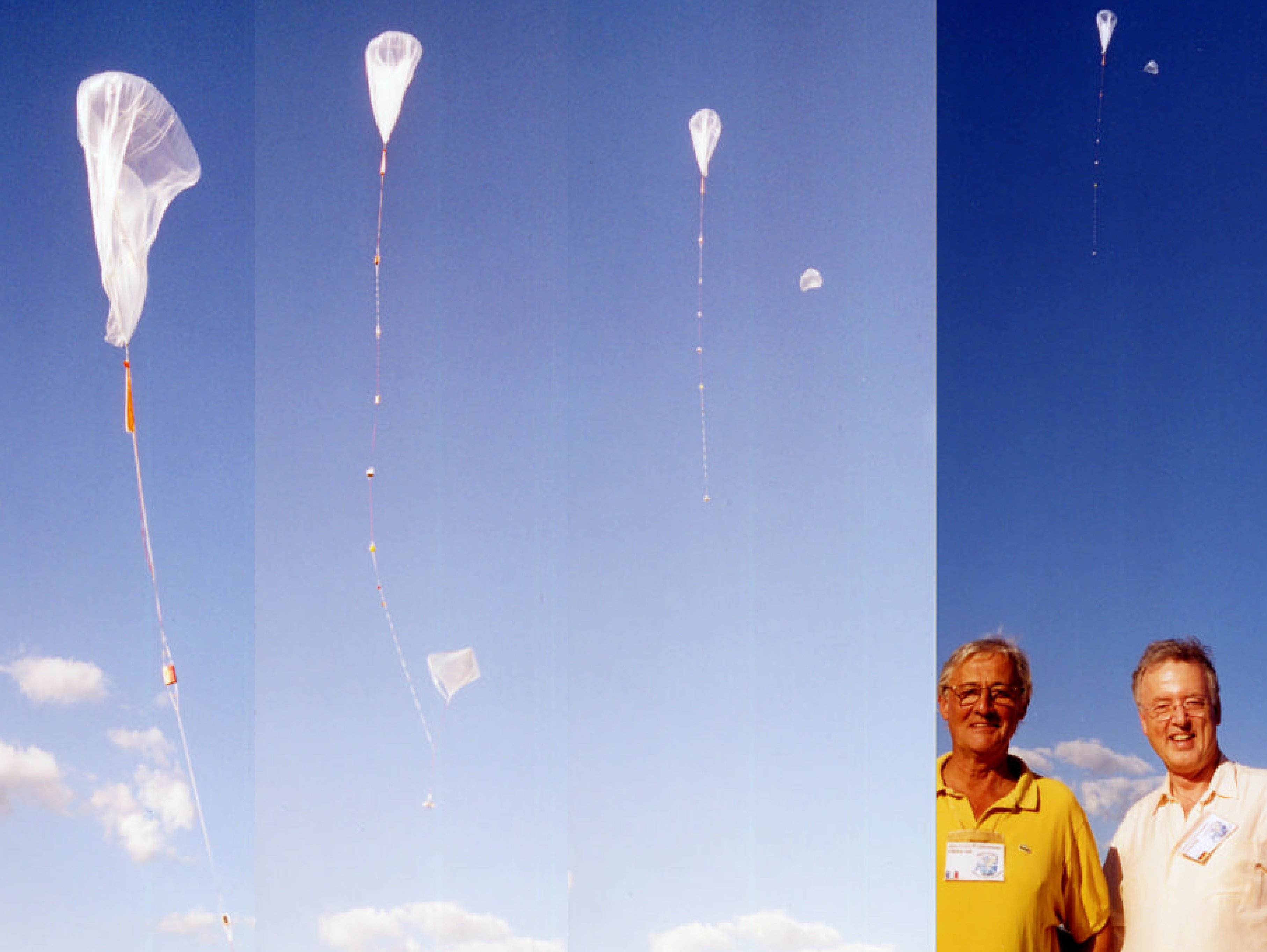


HIBISCUS-TROCCINOX Comparisons

H_2O:

F2 on 13 Feb 2004 : no DIAL data

F1 on 16 Feb 2004 : reasonable agreement

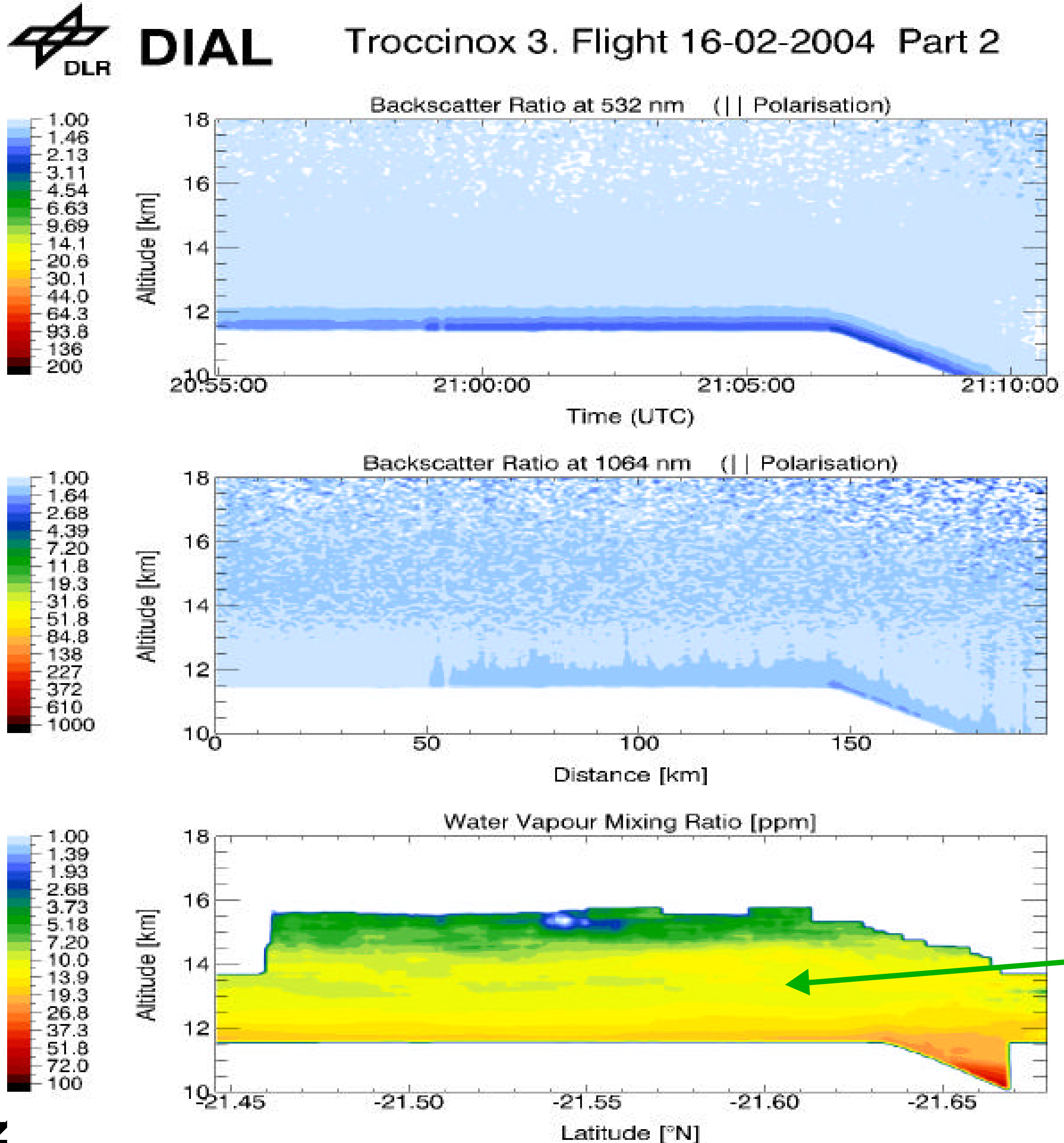
F3 on 26 Feb 2004 : 12 h time-shift to Falcon start on 27 Feb

Þ Dx > 400 km

F4 on 24 Feb 2004: no Falcon flight

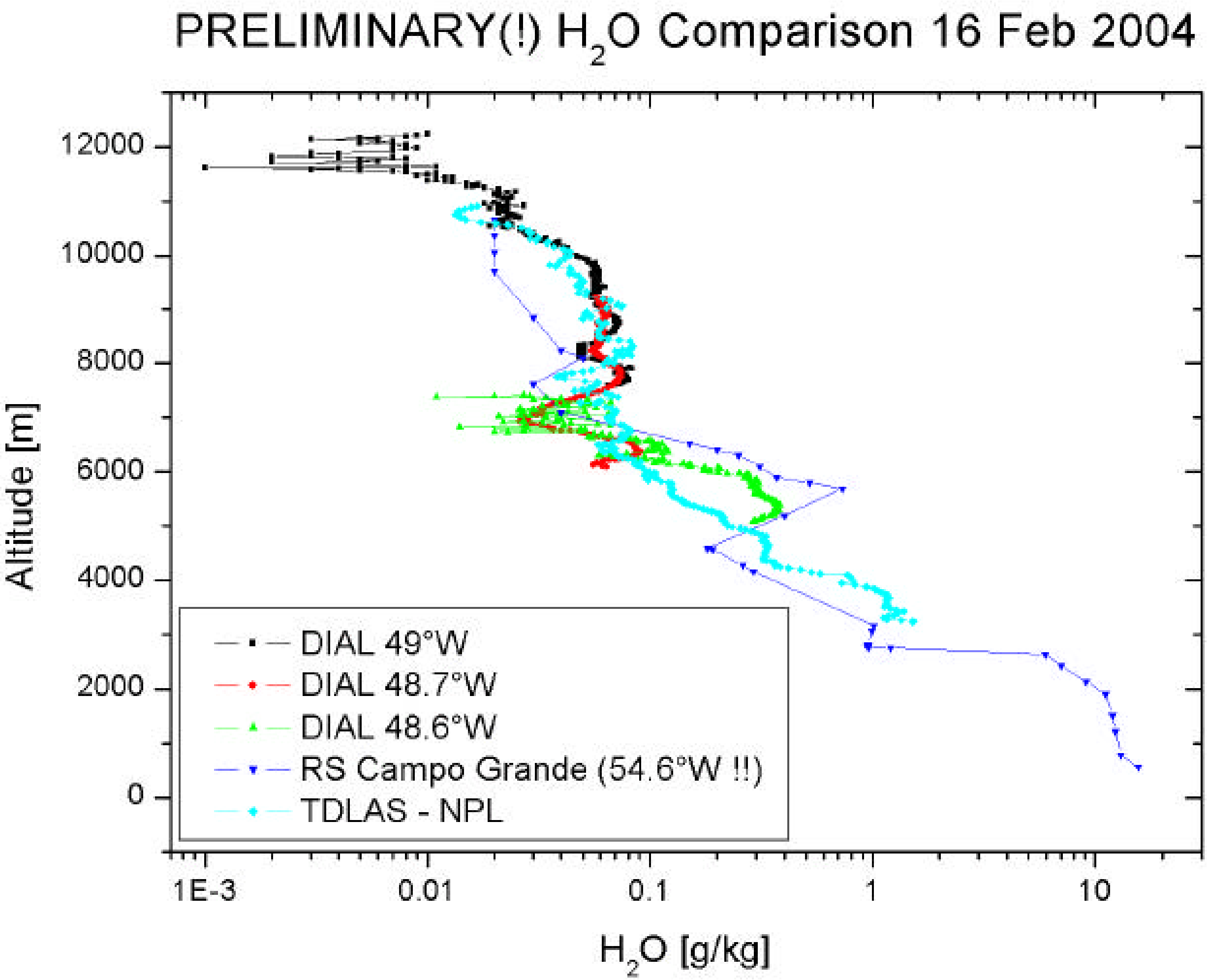
NO_2, O_3, etc.?

H_2O DIAL for Comparisons with 16 Feb 2004 - SF1



Very dry upper troposphere

Comparison of H_2O from DIAL, TDLAS (SF1) and Radiosonde, 16 February 2004



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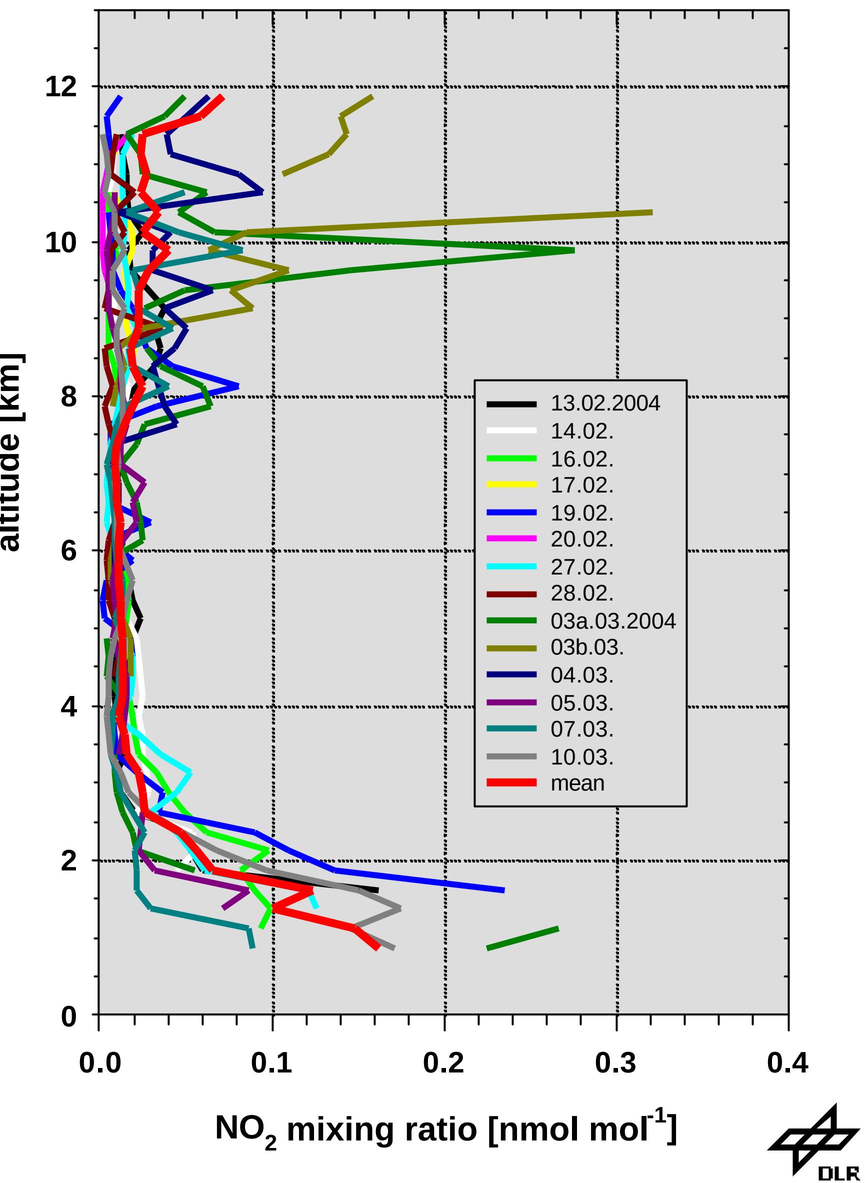
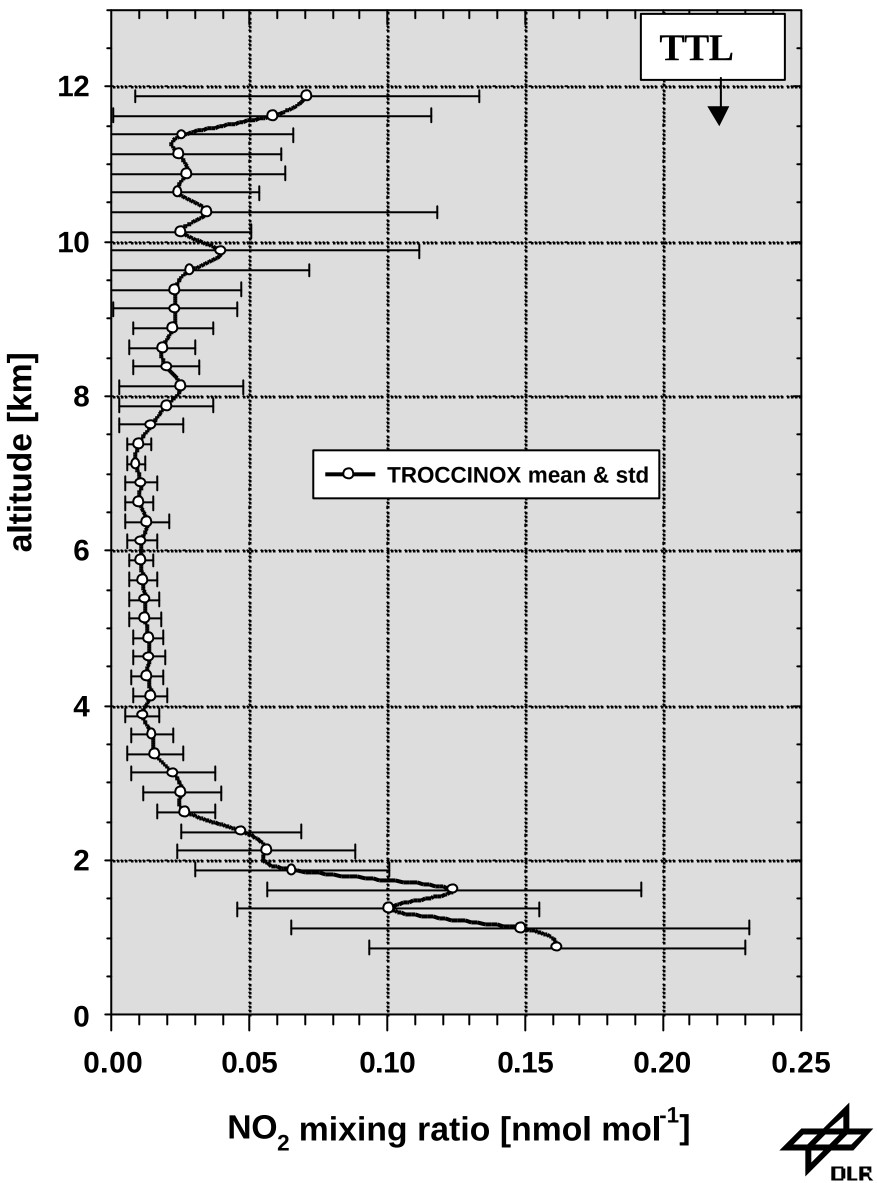
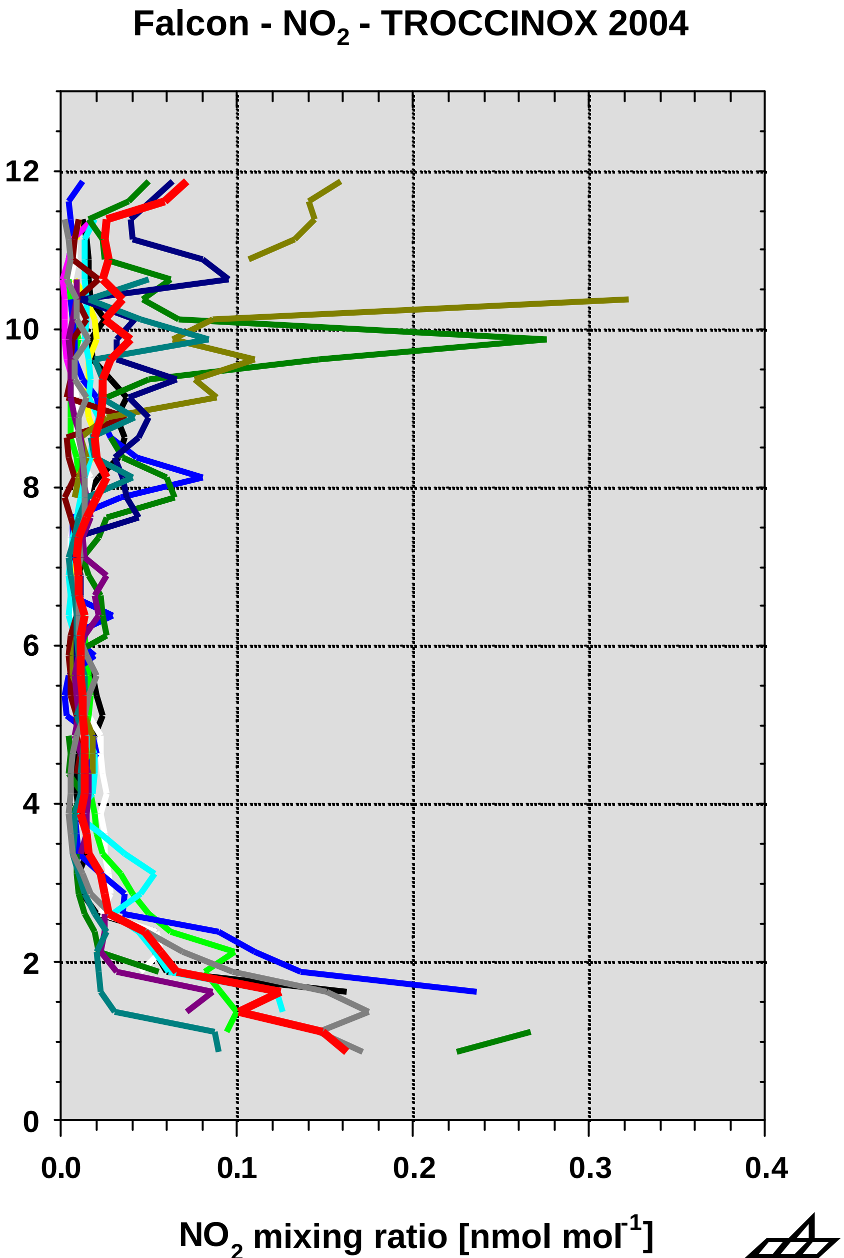
Falcon - NO_2 - TROCCINOX 2004

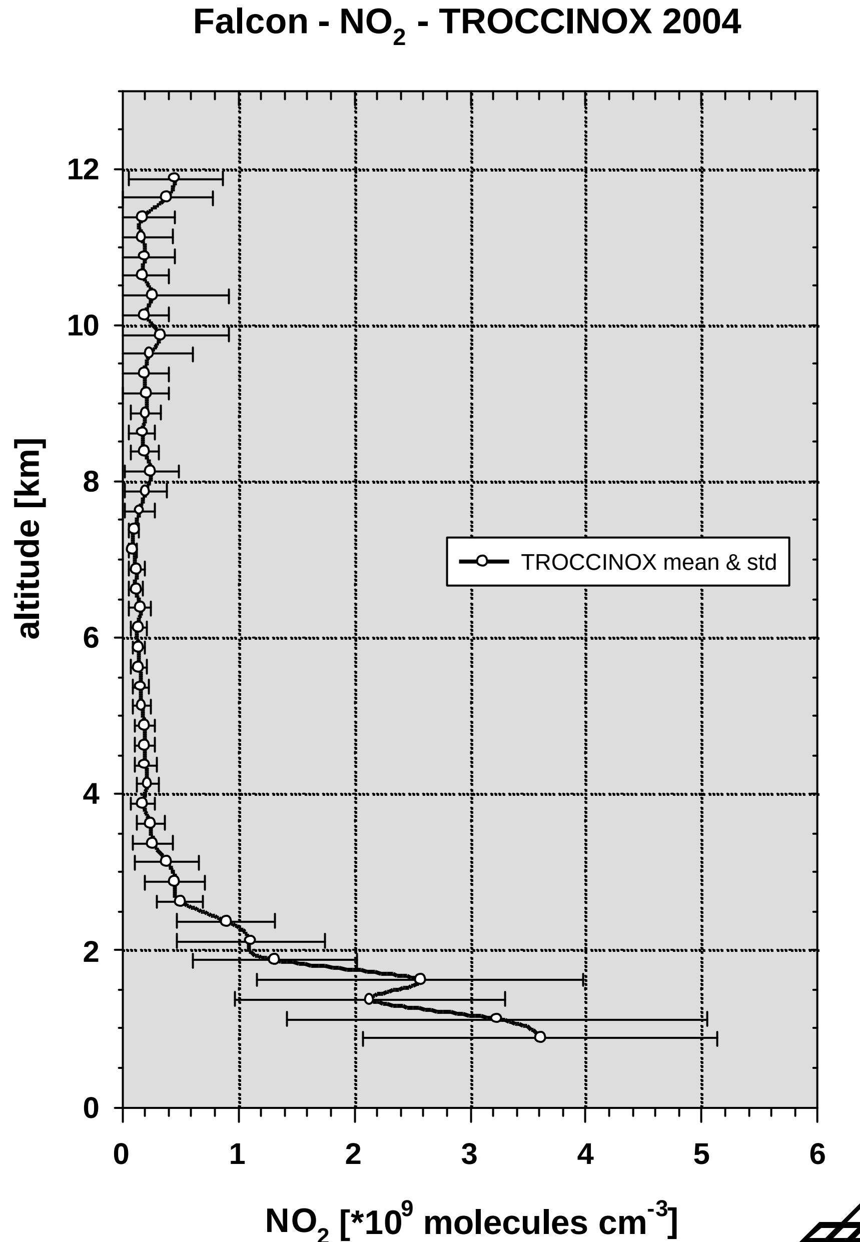


Falcon - NO_2 - TROCCINOX 2004





Falcon - NO2 - TROCCINOX 2004
0
2
4
6
8
10
12
0.0
0.1
0.2
0.3
0.4
NO2 mixing ratio [nmol mol-1]



Falcon - NO2 - TROCCINOX 2004
altitude [km]
0
2
4
6
8
10
12
0
1
2
3
4
5
6
TROCCINOX mean & std
NO2 [*10^9 molecules cm^-3]

Conclusions

- First systematic study of continental thunderstorms in the tropics, with subtropical and tropical thunderstorms
- Wide (several 10 km) spikes indicate outflow from a thunderstorm anvil, narrow (up to 65 nmol mol^{-1}, order 200 m) indicate fresh lightning events.
- Three TROCCINOX case studies indicate lower bounds for global lightning-NO_x production rates of 2 to 9 Tg(N) yr^{-1}.
- Model Comparison for 7 TROCCINOX case studies suggest good agreement with ECHAM model for 3 to 7 Tg(N) yr^{-1} (Preliminary)
- Important results from aerosols and H_2O Lidar
- NOx maximum above 12.5 km. Geophysica needed
- Therefore TROCCINOX-2 from Araçatuba 26.1-24.2.05

Geophysica M55 *Instrumentation*